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JOURNAL OF PALEONTOLOGY

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A Scott Warthin, for The Paleontological Society.

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VOLUME 22 JULY, 1948 NUMBER 4

OSTRACODA FROM THE UPPER CRETACEOUS AND LOWER EOCENE OF MARYLAND, DELAWARE, AND VIRGINIA[1]

RUTH A. M. SCHMIDT
U. S. Geological Survey, Washington, D. C.

ABSTRACT—Fifty-four species of Ostracoda are described from the Upper Cretaceous and basal Eocene formations of Maryland, Delaware and Virginia, of which 20 are new. Seven new varieties are also recognized. Twenty-four species are from the Eocene Aquia formation, and 27 are from the Upper Cretaceous. The fossiliferous localities and samples are described. The Marshalltown, Mount Laurel, and Monmouth formations are easily distinguished from each other and from the overlying Eocene Aquia formation on the basis of ostracodes. The subdivision of the Aquia into two members—the Paspotansa and Piscataway—cannot be made on the basis of the Ostracoda. Correlations of the Monmouth with the Navarro of the Gulf Coast, and of the Aquia with the Hornerstown marl of New Jersey and the Wilcox of the Gulf Coast are supported.

Ontogenetic development of ostracodes by molting is discussed, with particular reference to the genus *Cythereis*. The dentition of certain Ostracoda from the Monmouth formation that are assigned questionably to *Haplocytheridea* differs slightly but consistently from that described for the genus.

INTRODUCTION

DURING World War II, the search for oil led to the Atlantic Coastal Plain, and several exploratory wells were drilled and cored. Some discrepancies were noted in the wells, especially at the boundary of the Cretaceous and Eocene, where beds of both Midway and Wilcox age were found in contact with the Cretaceous in different wells, although only Wilcox is known at the surface. Very little work has been done on the microfaunas from outcropping Cretaceous and Eocene deposits in the East, and there was little available information bearing on the microfaunas found in the cores. This study was begun in the summer of 1945, and the work was done between assignments for the Military Geology Unit.

Because of the discrepancies in well data, the present work was limited to material collected from surface exposures. Collections were first made at described sections of the Upper Cretaceous in Delaware, and the lower Eocene Aquia formation in Virginia, to establish reference faunas. Additional collections were then made along the strike between the two localities, mainly to find a fossiliferous contact between the lower Eocene and the Upper Cretaceous.

Carter's section (1937) of the Upper Cretaceous in Delaware was taken as the

[1] Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of Pure Science, Columbia University.

northern limit. The Marshalltown formation was included so that its fauna would be identified if encountered in contact with the overlying Eocene. Neither Marshalltown nor Mount Laurel strata were recognized south of the Chesapeake and Delaware Canal. The Monmouth formation, which was not present at the canal, is the only late Cretaceous fossiliferous formation found south of the Canal. The ostracode fauna of this formation in Maryland is very distinctive, and different from that of the Monmouth group (Mount Laurel sand and Navesink marl) of New Jersey and Delaware. One ostracode, *Haplocytheridea? plummeri*, is common to both Mount Laurel and Monmouth; and only *Brachycythere rhomboidalis* is common to both Navesink and Monmouth.

The type section of the Aquia formation at Aquia Creek, Virginia, was described by Clark (1901) and by Gildersleeve (1942) The Piscataway indurated marl and Paspotansa greensand marl members are represented at the type locality, but they cannot be distinguished on the basis of their ostracodes. Four other localities of the Aquia have been described. There are many localities of fossiliferous Aquia, but at a number of them the beds are leached, the fossils replaced by limonite, and only casts or molds remain.

The only contact between fossiliferous Upper Cretaceous and Eocene has been found in a stream west of Friendly, Maryland (locality E, p. 398) where the Monmouth formation is succeeded upstream by the Aquia formation. Other streams in the vicinity were visited, but the Monmouth formation is so weathered that no fossils are preserved. At Brooks Estate (a locality mentioned in Maryland Geological Survey Upper Cretaceous volume, p. 95), only molds or casts of macrofossils were found in the Upper Cretaceous, although the Aquia specimens are well preserved. At other localities where the formations are presumed to be in contact, no fossils at all were discovered.

Changes in lithology that occur in these formations, resulting from original deposition, weathering, or the leaching action of the ground water, make correlation difficult on the basis of any one criterion. In one stream deposit of the Aquia, for example, a very fossiliferous zone was found. Less than 20 feet away, in a continuation of the same zone with exactly the same lithology, there was not a trace of shell fragments or fossil remains.

With such faunal and lithologic changes evident in the field, the difficulties of correlating cores from widely separated wells are obviously even greater. The author believes that because of these rapid local changes, reliable correlation of the beds of the Atlantic Coastal Plain must be based on detailed sedimentary, paleontological, and ecological studies.

The geomorphology of the Chesapeake Bay region is unique. This long shallow estuary situated on a coastal plain, fed by numerous rivers, and affected by the tides, has no counterpart in this hemisphere but there is as yet no reason to believe that similar conditions may not have existed in late Mesozoic and Cenozoic times in the same area. Outcrops are scattered, the soil cover is thick and concealing, and at many places the formations are discontinuous. This discontinuity might be explained by erosion during the Pleistocene when so many terrace gravels were deposited. A more accurate explanation and a better basis for correlating the discontinuous formations may only be formulated when more is known of actual conditions during late Cretaceous and Cenozoic times. The writer believes that for this reason the microfauna, the macrofauna, and the lithology of each formation should be carefully described.

As an additional aid to future workers, small vials of both unwashed field samples and washed material of each sample have been kept. It is hoped that this could be a more general practice, for it is one of the best records of the environment of the fauna, and may well prove to be important in later correlations.

Several interesting problems have arisen in the course of this work. Two of them are considered in detail in the section on taxonomy and morphology but others remain to be solved, as, for example, why certain beds are abundantly macrofossiliferous but devoid of microfossils.

ACKNOWLEDGEMENTS

The author expresses her appreciation to Dr. John B. Reeside, Jr., of the U. S. Geological Survey, who originally suggested this problem, and to Professor H. N. Coryell, of Columbia University, under whose supervision this work was done. Dr. E. S. Larsen 3d of the Military Geology Unit of the Geological Survey was most cooperative in enabling the writer to undertake this work. The study profited by the helpful criticisms and suggestions of numerous colleagues on the Geological Survey, especially Dr. Lloyd W. Stephenson and Dr. Julia Gardner. Dr. Chalmer L. Cooper was kind enough to read and criticize the manuscript.

I particularly wish to thank Miss Doris S. Malkin, formerly a fellow student at Columbia University and now with the Shell Oil Company, whose constructive criticisms and assistance in the field have been invaluable. Members of the Maryland Geological Survey, and Drs. R. S. Bassler and A. R. Loeblich, Jr., of the U. S. National Museum, have extended numerous courtesies to the author. The photographs were made by N. W. Shupe, and the pencil drawings by Elinor Stromberg, both of the U. S. Geological Survey.

PREVIOUS WORK

The first work on Ostracoda from Maryland and Virginia was done by E. O. Ulrich, and published in the Eocene volume of the Maryland Geological Survey in 1901. There is no reference to Ostracoda in the Maryland Upper Cretaceous volume published in 1916. A brief paper on a few Ostracoda from the Monmouth formation was published by E. Willard Berry in 1925. Eleven years later, in 1936, the microfaunas of the Monmouth and basal Eocene beds of New Jersey were described by P. H. Jennings. No other work on Ostracoda from the Cretaceous and Eocene beds of the Atlantic Coastal Plain has been published.

Ostracodes from equivalent formations of the Gulf Coastal Plain have been studied more thoroughly. A paper on the Upper Cretaceous Ostracoda of Arkansas was published by M. C. Israelsky in 1929. C. I. Alexander has written several papers on both Cretaceous and Eocene ostracodes from Texas. Henry V. Howe, with J. B. Garrett, and later with J. Chambers, described Louisiana Eocene species. Numerous papers on Eocene Ostracoda have been written by Morton B. Stephenson, in several of which he discussed the genus *Cytheridea*. There are many other authors who have worked with the early Tertiary Ostracoda, including Gooch, Hussey, Martin, Murray, Sutton, and Williams.

In Europe, excellent early work was done by T. Rupert Jones, C. D. Sherborn, and G. J. Hinde, and by Brady, Crosskey and Robertson, on both Cretaceous and Tertiary Entomostraca of England. In recent years, J. E. Van Veen has contributed to the knowledge of Upper Cretaceous Ostracoda from The Netherlands.

The most comprehensive stratigraphic works on the Cretaceous and Eocene deposits in Maryland, Delaware and Virginia are still the early Maryland and Virginia Geological Survey reports. W. B. Clark and G. C. Martin described the Eocene of Maryland (1901), and Clark and B. L. Miller reported on the physiography and geology of the coastal plain of Virginia (1912). In 1916 Clark, Berry, Gardner, and others described the Upper Cretaceous deposits of Maryland. Detailed accounts of the earlier geologic work in Maryland and Delaware have been presented by C. Carter, in 1937, and B. Gildersleeve in 1942 similarly discussed previous investigations of the Eocene of Virginia. A correlation chart of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal Plains prepared under the auspices of the National Research Council, by Lloyd W. Stephenson, P. B. King, W. H. Monroe, and R. W. Imlay, was published in 1942. The Monmouth formation at the latitude of Baltimore is correlated in this chart with the Mount Laurel sand and Navesink marl (formations comprising the Monmouth group) of New Jersey; the Pedee formation of the Carolinas; the Ripley formation in the eastern Gulf Coast; the Nacatoch sand in Arkansas and the Navarro group in Texas. In 1943 the correlation chart on the Cenozoic formations by C. Wythe Cooke, Julia Gardner, and Wendell P. Woodring ap-

peared. In it the Aquia formation is correlated with the Hornerstown marl and Vincentown sand in New Jersey, and the Wilcox group or formation in the Gulf States.

These correlations are supported by the few previously reported ostracodes described in this paper.

STRATIGRAPHY

General Statement

The area discussed in this paper lies entirely within the Atlantic Coastal Plain province. To the immediate west is the Piedmont province, and still farther west the Blue Ridge. The complex igneous and metamorphosed sedimentary rocks of these two westerly provinces provided a source for the Mesozoic and Tertiary sediments of the Coastal Plain province. The surface of the older crystalline rocks dips gently southeastward, and these rocks form the basement complex upon which the sediments of the Coastal Plain were deposited.

In Maryland and northern Virginia the outcropping deposits of the Coastal Plain range in age from Lower Cretaceous to Recent and in Delaware from Upper Cretaceous to Recent. The dip in general is gentle and toward the southeast. The strike of the beds is generally northeastward, becoming more northerly in southern Maryland. Southward the younger formations crop out successively farther and farther seaward, and are interrupted by Chesapeake Bay.

The Eocene beds progressively overlap and cut out the Cretaceous formations as they extend into Virginia. In Maryland, the Eocene beds overlie the Upper Cretaceous Monmouth formation; in Virginia, the Potomac group of Lower Cretaceous age.

The Monmouth group is subdivided into three formations in northern New Jersey and into two in Delaware. Near Washington it cannot be subdivided, and is considered to be a formation. In New Jersey the Monmouth group lies on the Wenonah sand, the uppermost formation of the Matawan group. This sand is cut out in northern Delaware, where the Mount Laurel sand of the Monmouth group rests on the Marshalltown formation of the Matawan group. The Matawan has not been subdivided south of the Chesapeake and Delaware Canal, but the author has recognized typical Englishtown sand and Crosswicks clay on both sides of Chesapeake Bay. Possibly the Marshalltown is cut out to the south. In Virginia no marine Upper Cretaceous strata occur at the surface.

TABLE 1.—UPPER CRETACEOUS AND LOWER EOCENE FORMATIONS

	Virginia	Maryland	N. Delaware	New Jersey
Eocene (lower)	Pamunkey group Nanjemoy formation Aquia formation Paspotansa member Piscataway member	Pamunkey group Nanjemoy formation Aquia formation Paspotansa member Piscataway member	Aquia formation ?Rancocas formation	Rancocas group Vincentown sand Hornerstown marl
Upper Cretaceous	ABSENT	Monmouth formation	Monmouth group Navesink marl Mount Laurel sand	Monmouth group Redbank sand Tinton sand member Navesink marl Mount Laurel sand
		Matawan formation	Matawan group Marshalltown formation Englishtown sand Crosswicks clay	Matawan group Wenonah sand Marshalltown formation Englishtown sand Woodbury clay Merchantville clay
		Magothy formation	Magothy formation	Magothy formation
		Raritan formation	Raritan formation	Raritan formation
Lower Cretaceous	Potomac group	Potomac group	Potomac group	

Upper Cretaceous

Marshalltown formation

Areal extent. The Marshalltown formation

of the Matawan group extends from northern New Jersey southwestward to the Chesapeake and Delaware Canal in Delaware. It has not been identified farther south although exposures of the underlying Englishtown and Crosswicks formations have been found on both sides of Chesapeake Bay.

Lithology. The Marshalltown formation is dark green-blue clayey marl with much glauconite. Where fossils were collected, it is a compact, glauconitic, marly clay, slightly micaceous, with many well-preserved fossils.

Stratigraphic relations. The Marshalltown unconformably overlies the Englishtown sand, and is unconformable below the Mount Laurel sand, from which it may be distinguished by lithologic character and faunal content, at locality A (p. 396). The Wenonah sand, present in New Jersey between the Marshalltown formation and the Mount Laurel sand, is absent in the canal area.

Correlation. Field tracing (Carter, 1937) and the occurrence of the *Exogyra ponderosa* zone is the basis for correlation with the Marshalltown formation of New Jersey and the upper Taylor of the Gulf Coast.

Mount Laurel sand

Areal extent. The Mount Laurel sand extends from northern New Jersey, southwestward to the Chesapeake and Delaware Canal in Delaware. It is not known in surface outcrops farther south.

Lithology. The Mount Laurel is a light-gray to white, mealy, compact, marly and sandy clay. It is very fossiliferous.

Stratigraphic relations. The Mount Laurel unconformably overlies the Marshalltown formation in the canal area, from which it may be distinguished by its faunal and lithologic characters, and is overlain unconformably by Pleistocene gravels and sands. The Navesink marl is absent in the canal area.

Correlation. This is the southwestward continuation of the formation from its type locality in New Jersey (Carter, 1937). It includes the *Exogyra cancellata* zone and hence is correlated with the Saratoga chalk of Arkansas, the Ripley formation of Alabama, and the lower Navarro of Texas.

Monmouth group or formation

The Monmouth group, as defined in Delaware and New Jersey, includes in ascending order, the Mount Laurel sand, Navesink marl and Redbank sand. In Maryland, west of Chesapeake Bay, where no such subdivision has been made, the Monmouth is a formation.

Areal extent. The Monmouth is recognized in Maryland in scattered outcrops from the Delaware border to southern Prince Georges County, a few miles south of the District of Columbia.

Lithology. The dark gray-green to black micaceous glauconitic sand of the Monmouth weathers to a reddish-brown, fairly compact deposit with indurated bands of iron ore locally. In some unfossiliferous localities, it is a reddish-brown sand, with only a few grains of glauconite.

Stratigraphic relations. The Monmouth unconformably overlies the Matawan, and to the southwest, the Magothy formation; and is overlain unconformably by Eocene, Miocene, or Pleistocene deposits.

Correlation. The Monmouth formation as recognized here includes the *Exogyra costata* zone, and is said to be equivalent in part to the Navesink marl of New Jersey, the Peedee formation of the Carolinas, the Ripley formation of Alabama and Mississippi, the Nacatoch sand of Arkansas, and the Navarro group of Texas. The ostracodes suggest its correlation with the Navarro group of Texas.

Eocene

The only formation of the Eocene series dealt with in this paper is the Aquia. In New Jersey, the Vincentown sand and Hornerstown marl constitute the Rancocas group, which is correlated with the Aquia formation of Maryland. An attempt was made to identify the Rancocas in Delaware. The old localities were visited, but no fossiliferous material was found.

Aquia formation

This formation was subdivided into the Piscataway and Paspotansa members by Wm. B. Clark and G. C. Martin (1901) because of faunal differences, but subdivision

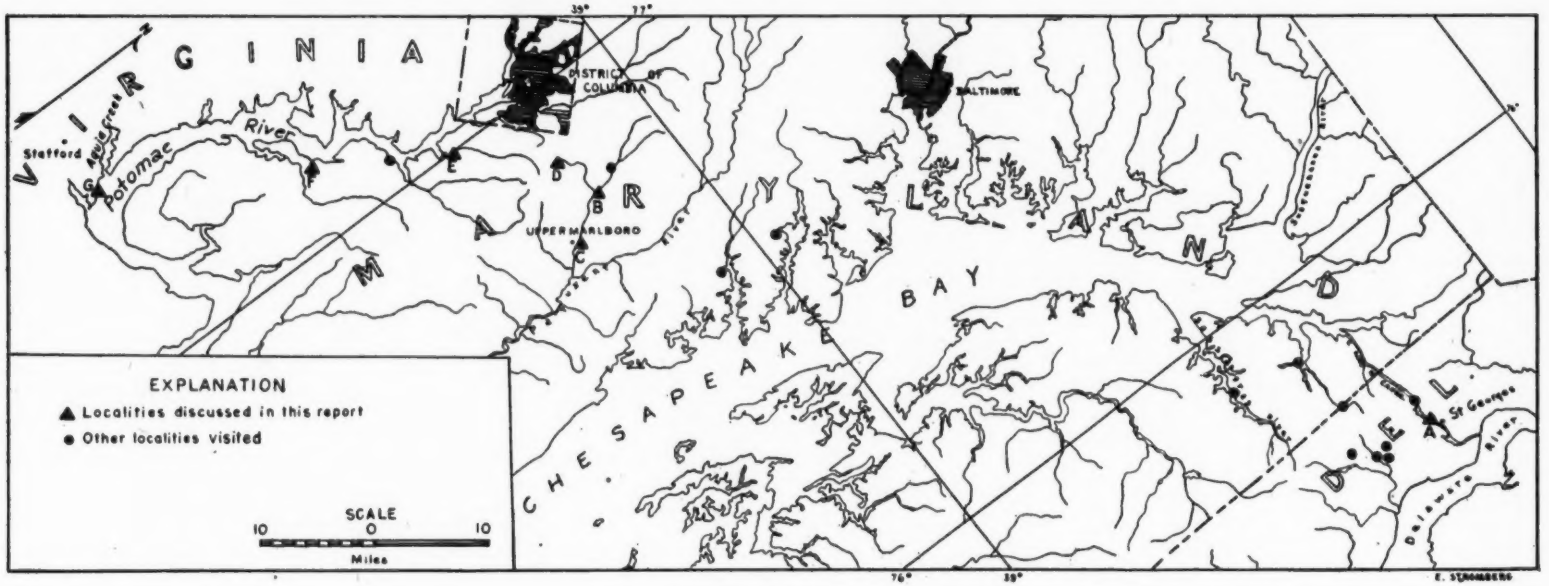


FIG. *1*—Upper Cretaceous and Lower Eocene localities in Maryland, Delaware, and Virginia.

on the basis of the ostracodes has not been successful.

Areal extent. The Aquia formation extends southwestward and south from the headwaters of Sassafras River, near the eastern shore of Maryland, to the vicinity of Richmond, Virginia. The type locality is at Aquia Creek, Virginia.

Lithology. The formation consists of glauconitic marl, sandy marl, clay, and locally, indurated shelly beds of impure limestone. Weathered deposits are light-tan to buff and mottled with varying amounts of iron, either as bands of limonitic iron-ore, or fossils completely replaced by limonite, as at South River, Maryland.

Stratigraphic relations. The Aquia formation unconformably overlies the Cretaceous formations; progressively overlapping beds from the Monmouth formation in northern Maryland to the Lower Cretaceous in the Potomac River Basin and Virginia.

Correlation. The Aquia formation has been correlated with Hornerstown marl of New Jersey by Cooke and Stephenson (1928), and with both the Hornerstown marl and Vincentown sand by Cooke, Gardner, and Woodring (1943). To the south it has been correlated with the Wilcox group of the Gulf Coastal Plain and the few ostracodes common to the two regions support this correlation.

LOCALITIES, SECTIONS AND SAMPLES

Numerous localities, including many that are mentioned in the Eocene and Upper Cretaceous reports of the Maryland Geological Survey, were visited and collections made and examined. The localities are indicated on the accompanying map. Those described in detail are the ones that yielded good microfaunas. Many outcrops possess a good macrofauna preserved as casts and molds, but no microfauna. Beds that formerly contained abundant calcareous fossils are generally leached and the shell material dissolved. Many beds have been replaced with limonite, and bands of bog iron, characteristically scattered through the formations, may mark former temporary levels of

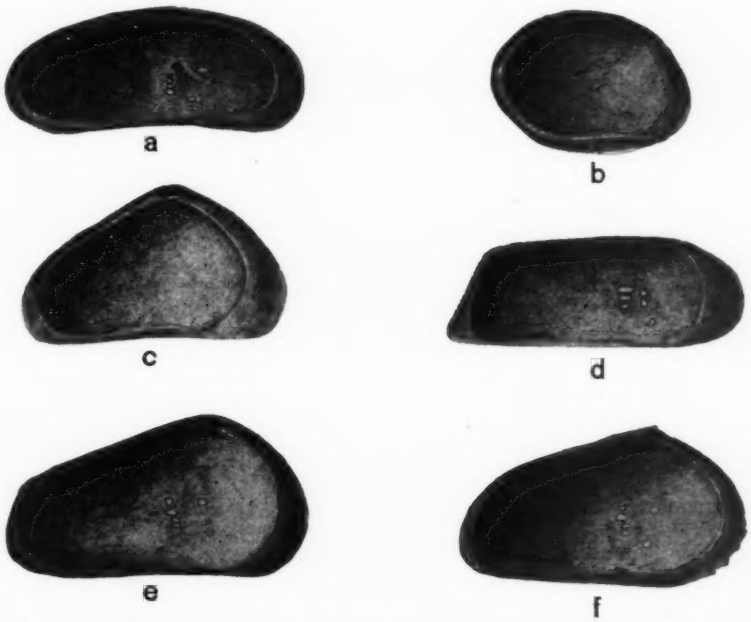


FIG. 2—Interior views of ostracodes, left valves. *a*, *Xestoleberis mayeri* (Howe and Garrett), length, 0.73 mm.; *b*, *X. opina* Schmidt, n. sp., length 0.48 mm.; *c*. *Eucythere triordinis* Schmidt, n. sp., length, 0.51 mm.; *d*, *Krithe postprojecta* Schmidt, n. sp., length 0.63 mm.; *e*, *Haplocytheridea? fabaformis* (Berry), length 0.65 mm.; *f*, *H.? plummeri* (Alexander), male, length 0.91 mm.

ground water. Fresh material may occur within concretions or inside the molds of large macrofossils at such localities but so far none have yielded a good microfauna.

Locality A. Chesapeake and Delaware Canal. U. S. Geol. Survey Wilmington, Del.-N. J. quad., 1: 62:500, 1906, reprinted 1944. Southeast part of map; south bank of canal, 0.8 mile southwest of B.M. 11, opposite town of St. Georges, Del. (Present bridge is west of bridge shown on map.) Bluff was about 2,500 feet west of Carter's (1937) Section XI, opposite marker 33 in canal.

The stratigraphic section at this locality is much like Carter's (1937, p. 274). This locality was revisited in November 1946 but the banks were then being stabilized, graded and cultivated. All Carter's sections east of Summit Bridge had been obliterated and work was in progress along the rest of the canal. When collections were made, the bluff was about 30–35 feet high. Measurements are approximate.

Pleistocene sand and gravel; 20 feet.

Unconformity

Mount Laurel sand

Brown micaceous glauconitic sand; no microfossils; macrofossils leached; 3 feet.

Field: White to light-gray mealy compact marly clay, highly fossiliferous; 3.2 feet. Sample A 2 from matrix of *Exogyra cancellata.*

Washed: Salt-and-pepper appearance, some red specks; yellower than Marshalltown formation. Quartz, glauconite, much limonite, some calcite, phosphate nodules, ostracodes, Foraminifera, shell fragments.

Unconformity

Marshalltown formation

Field: Dark-green to blue compact micaceous highly glauconitic marly clay. Highly fossiliferous; thickness to beach, 2.3 feet. Sample A 1.

Washed: Dark-green speckled with white. Mostly glauconite, some quartz, muscovite, phosphate nodules, ostracodes, Foraminifera, sharks teeth, shell fragments.

Locality B. Oakgrove. U. S. Geol. Survey Upper Marlboro, Md.-D. C. quad., 1: 62,500, 1938, reprinted 1943. East-central part of map; road-cut 0.65 mile west of Oakgrove, Md., on Route 202. About 0.12 mile east of Western Branch of Patuxent River on north side of road; approximately 5 miles north-northwest of Upper Marlboro, Prince Georges Co., Md. Approximately 15 to 20 feet of weathered greensand. Piscataway member of the Aquia formation (Stephenson, L. W., 1937, p. 59). Zones not persistent.

Field: Dark-green, mottled, very glauconitic, micaceous sand, scattered with limonite, unfossiliferous; about four feet thick at west end of cut. *Sample B8.*

Washed: Mostly glauconite; quartz, some mica and limonite; no fossils.

Field: Uppermost indurated ledge, width irregular, lime-cemented, much altered to limonite, fossiliferous, *Cucullaea* molds. *Sample B7.*

Washed: Rusty speckled sand, quartz, glauconite, limonite, shell fragments, few Foraminifera and ostracodes, either molds or too weathered for certain identification.

Field: Loose beige marl, fine-grained, fossiliferous; *Cucullaea* molds. *Sample B6.*

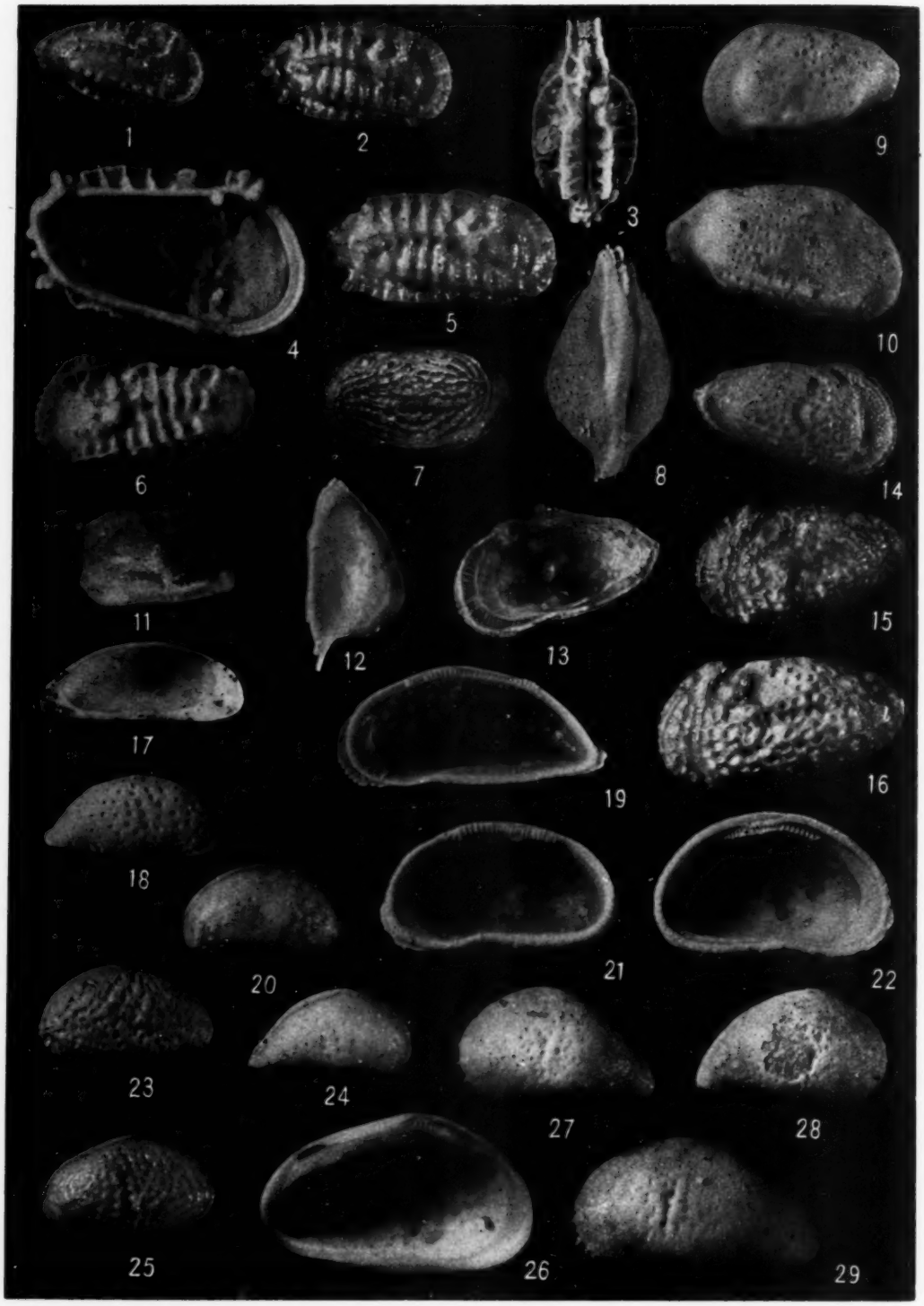
Washed: Quartz, glauconite, some limonite

Explanation of Plate 61

Figures ×40 unless otherwise indicated

Fig. *1*—*Cytherelloidea spiralia* Jennings. Right valve. (p. 406)
2—*Cytherella* cf. *beyrichi* (Reuss). Left valve. (p. 406)
3—*Cytherella ovata* (F. A. Roemer). Right valve. (p. 405)
4—*Cytherella* sp. Left valve, male. (p. 406)
5, 6—*Cytherella* sp. Female; *5*, left valve; *6*, right valve. (p. 406)
7—*Cytherelloidea monmouthensis* Jennings. Right valve. (p. 407)
8—*Krithe postprojecta* Schmidt, n. sp. Left valve. (p. 409)
9—*Monoceratina biloba* Schmidt, n. sp. Left valve. (p. 412)
10—*Monoceratina pedata* (Marsson). Left valve. (p. 411)
11–13—*Cythereis communis* Israelsky. *11, 12*, left valves; *13*, right valve. (p. 419)
14—*Paracythereis semilenis* Schmidt, n. sp. Left valve. (p. 418)
15, 16—*Xestoleberis opina* Schmidt, n. sp. *15*, left valve; *16*, right valve. (p. 410)
17, 18—*Cythereis costalana angula* Schmidt, n. var. *17*, left valve, *18* dorsal view. (p. 420)
19, 20—*Cythereis bassleri vacuitalis* Schmidt, n. var. *19*, dorsal view; *20*, right valve. (p. 423)
21, 22—*Bairdoppilata pondera* Jennings. *21*, interior, left valve; *22*, right valve. (p. 408)
23, 24—*Brachycythere alata atlantica* Schmidt, n. var. *23*, left valve; *24*, dorsal view, right valve (p. 415)
25, 26—*Haplocytheridea pinochii* (Jennings). *25*, interior, left valve ×60; *26*, left valve. (p. 427)
27–31—*Haplocytheridea punctura* Schmidt, n. sp. *27*, left valve, female; *28*, left valve, male; *29*. right valve, male; *30*, interior, right valve, male, ×60; *31*, interior left valve, female, ×60, (p. 425)

Schmidt, Cretaceous and Eocene Ostracodes



Schmidt, Cretaceous and Eocene Ostracodes

and mica, highly fossiliferous, Foraminifera abundant, ostracodes, sharks teeth, shell fragments. Calcite crystals have started to grow on many of the ostracode shells, making specific identification questionable. This condition not noted in other samples.

Field: Prominent, indurated, beige, calcareous ledge about 8 to 12 inches thick, fossiliferous. *Sample B5.*

Washed and crushed: Beige sand, quartz, calcareous clay cement, glauconite, some mica, many Foraminifera, some ostracodes.

Field: Loose, highly fossiliferous, light-beige, shelly marl, just beneath indurated ledge, numerous *Cucullaea* molds. *Sample B4.*

Washed: Fine- to medium-grained marl, quartz, some glauconite, numerous shell fragments, Foraminifera and ostracodes, almost a foraminiferal marl in finer-size grades.

Field: Slightly indurated calcareous layer, fossiliferous. *Sample B3.*

Washed: Quartz, glauconite, mica, shell fragments, no microfossils observed.

Field: Loose shelly zone just beneath indurated layer, few feet above road at west end of cut. *Sample B2.*

Washed: Salt-and-pepper sand, quartz, glauconite, some mica, limonite, and rarely, a black opaque mineral; many shell fragments, numerous Foraminifera, rare ostracodes.

Field: Loose, rust-colored glauconitic sand, base of section at west side of cut. *Sample B1.*

Washed: Quartz, glauconite, mica, limonite, no fossils.

Locality C. Upper Marlboro. U. S. Geol. Survey Upper Marlboro, Md.-D. C. quad., 1: 62,500, 1938, reprinted 1943. East edge of map; 0.6 mile south of 38° 50′ coordinate. East of Route 202, about 0.4 mile north of junction with U. S. 301 in town of Upper Marlboro, Prince Georges Co., Md.

The old Upper Marlboro locality was in hill on west-facing slope above Western Branch, and subsequent collections have been made in road-cut of Route 202 through the hill. This is the section described in Maryland Geol. Survey Eocene volume (Clark and Martin, 1901, p. 72). In spring of 1946, the outcrop was so weathered that only imprints and traces of fossils were seen. Collections were made in woods about 500 feet east of road at the base of hill, where an indurated fossiliferous ledge of the Aquia formed a bank about 6 feet high. On the basis of macrofauna, this ledge has been identified as the Paspotansa stage of the Aquia (Clark and Martin, 1901).

Field: Shelly, gray-green, glauconitic marl, 1 inch to 2 feet in thickness. *Sample C3.*

Washed: Salt-and-pepper sand, quartz, glauconite, some limonite, many shell fragments, small Foraminifera abundant, some ostracodes.

Field: Indurated, gray fossiliferous ledge about 5 feet thick. *Sample C2.*

Washed: Beige sandy marl, quartz, some glauconite, rare phosphate nodule, shell fragments, small Foraminifera abundant, some ostracodes.

Field: Loose, gray-green, glauconitic, shelly marl, just beneath indurated layer, base concealed by soil and vegetation. *Sample C1.*

Washed: Salt-and-pepper sand, quartz, glauconite, some limonite, many shell fragments,

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Explanation of Plate 62

Figures ×40 unless otherwise indicated

Fig. *1*—"*Archicythereis*" cf. *Cythereis pidgeoni* Berry. Right valve. (p. 417)

2–6—*Cythereis pidgeoni* Berry. *2–4*, females *5*, *6*, males. *2*, *5*, right valves; *3*, dorsal view, complete specimen; *4*, interior, left valve, ×60; *6*, left valve, worn specimen. (p. 421)

7—*Loxoconcha cretacea* Alexander. Left valve, ×60. (p. 412)

8–10—*Brachycythere rhomboidalis* (Berry). *9*, left valve, molt; *8*, dorsal view; *10*, right valve. (p. 414)

11, *12*—*Cytheropteron* (*Cytheropteron*) *coryelli* Schmidt, n. sp. *11*, right valve; *12*, dorsal view right valve. (p. 413)

13–16—*Brachycythere arachoides* (Berry). *13*, interior, right valve, female; *14*, right valve, molt; *15*, left valve, female; *16*, left valve, male. (p. 415)

17—*Paracypris monmouthensis* Schmidt, n. sp. Left valve. (p. 408)

18, *19*—*Haplocytheridea? ulrichi* (Berry). *18*, right valve; *19*, interior, right valve, ×60. (p. 426)

20–22—*Haplocytheridea? amygdaloides brevis* (Cornuel). *20*, right valve. *21*, interior, right valve, ×60; *22*, interior, left valve, ×60. (p. 426)

23—*Haplocytheridea? fabaformis* (Berry). Left valve. (p. 426)

24—*Haplocytheridea? macropora* (Alexander). Right valve. (p. 425)

25, *26*—*Haplocytheridea? fabaformis multilira* Schmidt, n. var. *25*, right valve; *26*, interior, left valve, ×60. (p. 426)

27–29—*Haplocytheridea? plummeri* (Alexander). *27*, left valve, female; *28*, right valve, female; *29*, left valve, male. (p. 425)

TABLE 2.—OCCURRENCE AND ABUNDANCE OF OSTRACODES IN UPPER CRETACEOUS FORMATIONS

	Upper Cretaceous						Occurrences Listed by Other Authors		
	Matawan group	Monmouth group							
			Monmouth formation						
	Marshalltown Canal, Del.	Mount Laurel Canal, Del.	Addison Road, Md.	Brightseat, Md.	Friendly, Md.	Friendly, Md.	Israelsky	Alexander	Jennings
Collecting Localities	A 1	A 2	D 1		E 2	E 3	Arkansas	Texas	New Jersey
Monoceratina pedata	R						Ozan, Marlbrook Annona, Saratoga	Gober Annona Lower Taylor	
Monoceratina biloba n. sp.	R								
Krithe postprojecta n. sp.	C								
Haplocytheridea punctura n. sp.	VA								
Cythereis bassleri vacuilatis n. var.	C								
Cythereis costatana angula n. var.	A	C							
Cythereis communis	A	A					Ozan, Marlbrook Annona, Saratoga Nacatoch, Arkadelphia	Navarro	Mt. Laurel Navesink
Xestoleberis opina n. sp.	A	R							
Brachycythere alata atlantica n. var.	R	C							
Cytherelloidea spiralia	R	R							Mt. Laurel Navesink
Cytherelloidea monmouthensis		C							Navesink
Bairdoppilata pondera		VA							Mt. Laurel Navesink
Paracythereis semilenis n. sp.		R							
Haplocytheridea pinochii		R							Mt. Laurel
Haplocytheridea? plummeri		A	C			C		Taylor	
Brachycythere rhombodalis			R	C		C		Navarro	Navesink
Brachycythere arachoides			A	C	C	VA			
Brachycythere arachoides (molt)			C	R	C	C			
Cytheropteron (C.) coryelli n. sp.				R					
Loxoconcha cretacea				R				Lower Navarro	
Paracypris monmouthensis n. sp.						R			
Haplocytheridea? fabaformis			C	C	C	C		Navarro Basal Kincaid	
Haplocytheridea? fabaformis multilira n. var.						R			
Haplocytheridea? macropora			R	C		C		Upper Navarro	
Haplocytheridea? amygdaloides brevis			C	C		C		Upper Goodland Kiamichi	
Haplocytheridea? ulrichi				R	R	R			
"*Archicythereis*" cf. *Cythereis pidgeoni*						R			
Cythereis pidgeoni			C	C	C	A			
Cytherella ovata	C							Goodland Kiamichi	
Cytherella cf. *beyrichi*	R			R					
Cytherella sp. male	C			R		R			
Cytherella sp. female	R								

For average washed sample: Rare (R) = 1 or 2 specimens. Common (C) = 3 to 7 specimens.

numerous Foraminifera in small sizes; no ostracodes, material looks reworked.

Locality D. Addison Road. U. S. Geol. Survey Washington East, Md.-D. C. quad., 1: 31,680, 1945 (also on Washington and vicinity, Md.-Va.-D. C. quad.). Southeast corner of map; in bank of Cabin Branch which is just west of Addison Road at a point 0.7 mile south of Central Avenue.

Field: Dark-blue to black micaceous, glauconitic shelly sand; weathered to dirty brown on surface; forms compact bank, but crumbles easily; fossiliferous. *Sample D1.*

Washed: Micaceous gray-green sand, quartz, muscovite, biotite, glauconite, some calcareous clay particles, shell fragments, many Foraminifera and ostracodes; similar to topotype material from Brightseat, Md.

Locality E. Friendly. U. S. Geol. Survey Anacostia, Md.-D. C. quad., 1: 31,680, 1945. (Also on Washington and Vicinity, Md.-Va.-D.C. quad.) Southwest corner of map; stream south of road leading west from Friendly, Md. Aquia formation (Samples E-4, E-5) crops out 0.5 mile west of Friendly; Monmouth formation farther downstream.

The Aquia (probably Piscataway member) and Monmouth formations are in contact in this stream bed, but the actual boundary is difficult to locate. About one or two feet of it was seen beneath the roots of an overhanging tree. Pleistocene and Recent deposits overlie both formations and locally conceal them. The Aquia and Monmouth are both dark-green, glauconitic, shelly marls and are very difficult to distinguish in the field. The Monmouth weathers to a dirty brown more commonly, and contains more mica, which can not always be detected in the field. Where the stream cuts through the Aquia, great numbers of *Cucullaea* molds occur in the stream bed.

Aquia formation.

Field: Bank of stream, just below small concrete dam. About 3 feet of dark-green, glauconitic, shelly marl; compact, hard, but not indurated; very fossiliferous. *Sample E5.*

Washed: Salt-and-pepper sandy marl, quartz, glauconite, rare limonite, some mica, many shell fragments, abundant Foraminifera, many ostracodes.

Field: Indurated layer in bed of stream a few feet downstream from sample E5; dark green-gray, glauconitic, shell marl. *Sample E4.*

Washed and crushed: Quartz, glauconite, some limonite, some mica, many shell fragments, many small Foraminifera, few ostracodes.

Monmouth formation.

Field: About 500 to 600 feet farther downstream, just before stream swings toward road, last very fossiliferous bed in bank. Dark-green glauconitic fossiliferous marl. *Sample E3.*

Washed: Salt-and-pepper, micaceous sand, quartz, glauconite, muscovite, some dark mica, some black opaque minerals, shell fragments, numerous Foraminifera and ostracodes.

Field: Just at large curve in stream, bank about 3 feet high. Dark-green glauconitic sand, weathered brown. No fossils seen. *Sample E2.*

Washed: Grayish-green micaceous sand, quartz, glauconite, muscovite, some limonite, black opaque minerals, few shell fragments, Foraminifera and ostracodes.

Field: About 100 to 200 feet farther downstream. Bank 1½ feet high, same lithologic character as E2 above, few shell fragments. *Sample E1.*

Washed: Same as E2 above. Many shell fragments, one fish vertebra, no microfossils.

Locality F. Glymont. U. S. Geol. Survey Indian Head, Md.-Va. quad., 1: 62,500, 1925, reprinted 1945. Center of map; east bank of Potomac River, 2,000 feet east-northeast of Glymont. Section described in Maryland Eocene volume (Clark and Martin, 1901, p. 68). Piscataway member of Aquia. Microfauna very scanty. Measurements indicated are from Clark and Martin (1901).

Aquia formation (Piscataway member)

Field: At top of section, beneath 20 feet of Pleistocene gravel and loam, is indurated ledge of light green-gray glauconitic sand, fossiliferous. *Sample F5.*

Washed: Quartz, glauconite, many shell fragments, calcareous cement, microfossils rare, more ostracodes than Foraminifera.

Field: Green marly sand, 1 to 1½ feet thick, not indurated where sampled, numerous macrofossils. *Sample F4.*

Washed: Much glauconite, quartz, some mica, numerous shell fragments, microfossils rare.

Field: Grayish-green fossiliferous sandy marl. *Sample F3.*

Washed: Quartz, glauconite, some mica, many shell fragments, rare microfossils.

Field: Argillaceous, glauconitic sand, sampled about 3 feet below lowest fossiliferous bed, and about 5 feet above contact with Lower Cretaceous; barren of fossils. *Sample F2.*

Washed: Quartz, glauconite, some limonite and mica.

Locality G. Aquia Creek. U. S. Geol. Survey Nanjemoy Md.-Va. quad., 1: 62,500, 1913, reprinted 1945. Also on Fredericksburg, Va.-Md. quad., 1: 125,000, 1894, reprinted 1944, West bank of Potomac, near mouth of Aquia Creek, S. 10° E. of Brent Point.

The section here is the one described and measured by Gildersleeve (1942, pp. 18–19). It is also described in the Maryland Geol. Survey Eocene volume, p. 69 (Clark and Martin, 1901), and Virginia Geol. Survey

TABLE 3.—OCCURRENCE AND ABUNDANCE OF OSTRACODES IN EOCENE FORMATIONS

	EOCENE																								Occurrences Listed by Other Authors			
	← Aquia fm. →																											
	Friendly, Md.		Aquia Creek Va.								Glymont Md.			Oak Grove Md.					Upper Marlboro Md.									
			Piscataway						Paspotansa		Piscataway			Piscataway					Paspotansa									
Collecting Localities →	E 4	E 5	G 1	G 2	G 3	G 5	G 6	G 7	G 11	G 14	F 3	F 4	F 5	B 2	B 4	B 5	B 6	B 7	C 2	C 3					Alexander	Jennings	Howe and Stephenson	
																									Texas	New Jersey	Louisiana	Alabama
Cytheropteron (C.) cf. *midwayensis*	R	A				R			?						R		R								{Base Wills Point			
Haplocytheridea veatchi aquia n. var.	R	A		R	A	A	C		C		R	R	C		R	C	R											
Haplocytheridea leei	R	A					C				R						R	?	C	C							Sabine	Nanafalia
Brachycythere marylandica		VA	R	R	A	A	C	R	A	A	A		R		VA	C	A	?	C	A						Hornerstown	Sabine	{Nanafalia Hatchetigbee
Bythocypris parilis		C				R	C		R	C							C		C							Hornerstown		
Xestoleberis mayeri		R																		R							Sabine	Nanafalia
"Archicythereis" reliplana n. sp.		R				R									R													
Cythereis siegristae n. sp.		VA			R	R							R		C	C	A			R								
Cythereis bassleri		R																										
Cytherelloidea truncata n. sp.							R	R								R												
Paracythereis potomaca n. sp.							R								C	C	R											
Paracypris strecca n. sp.						R				R																		
Clithrocytheridea virginica n. sp.						C			R										C									
Clithrocytheridea rugata n. sp.							R		R																			
Cythereis communis aquia n. var.									R																			
Cythereis bassleri reticulolira n. var.									R						VA		VA											
Clithrocytheridea tombigbeensis									R	R																	{Hatchetigbee Bashi	
Clithrocytheridea malkinae n. sp.									VA	C										C								
Eucythere triordinis n. sp.															R													
Cythereis pauca n. sp.															R													
Cythereis plusculmenis n. sp.															VA	A	VA			R								
Paracythereis plusculmenis n. sp.															R	R												
Xestoleberis longissima n. sp.															C		?		C									
Loxoconcha? sp.																R	R		R									
Cytherella cf. *beyrichi*										?					?													
Cytherella sp. male		R				R	R						R			R	R											
Cytherella sp. female		C							R								R			R								

For average washed sample:
Rare (R) = 1 or 2 specimens.
Common (C) = 3 to 7 specimens.
Abundant (A) = 8 to 14 specimens.
Very abundant (VA) = 15+ specimens.

Bull. 4 (Clark and Miller, 1912). The measurements are Gildersleeve's. Two or three samples were taken from some zones, as indicated.

The difference between the Piscataway and Paspotansa members of the Aquia formation at many places is difficult to recognize. They can be separated on the basis of their megafossils, but not by the ostracodes. At the type locality, however, these two members differ lithologically. The Piscataway consists of dark-green glauconitic marl, the Paspotansa of light-yellow, glauconitic sand.

Samples G 7 to 10 were taken in the zone described by Gildersleeve as "Dark-colored greensand, fossils very poorly preserved . . . 14 feet." This is probably zone 7 of Clark and Martin. At the lowest part of this zone (sample G 7), fossiliferous streaks are present locally. The three higher collections (samples G 8 to 10) had only impressions of megafossils, and no actual shell remains. Farther west in the same bluff shells were preserved much higher in the section. Depth of leaching apparently varied in this formation when it was exposed to post-Piscataway (or even post-Paspotansa) weathering. The irregular leached zone may represent a former ground-water table, and perhaps reflects the topography of that time. Subsequently, the Papotansa seas leveled the land, and the Paspotansa beds were deposited. The latter have probably been exposed longer than the lower member because the Paspotansa beds, in this area, are light yellow and less glauconitic. Possibly the smaller amount of glauconite indicates that the Paspotansa beds were not under the sea as long a period as the Piscataway beds.

Measurements and quotations are from Gildersleeve, detailed descriptions are the author's.

Pleistocene white sand, 20 feet

Paspotansa member of Aquia formation, Eocene. "Indurated layers with traces of *Turritella* and *Ostrea*, 4 feet, 6 inches."

Field: Light-yellow to yellowish-red indurated sand; gray, light or pale green where fresh; shells very abundant, *Ostrea compressirostra* conspicuous both in place and in slumped blocks. This layer is source of large brownish slumped blocks with *Turritella* (Clark and Martin, 1901, pl. III, fig. 2). *Sample G14.*

Washed and crushed: Quartz, some grains still firmly cemented with calcareous cement, some glauconite, limonite, mica, shell fragments, Foraminifera and worn ostracodes.

"Light-colored greensand; 18 feet."

Field: Light-yellow compact sand, not indurated, pale greenish where fresh, shelly layers, *Turritella* common. *Samples G11 to 13.*

Washed: Quartz, some glauconite, mica, grains cemented by limonite, no calcite or microfossils. *Sample G13.*

Washed: Quartz, some glauconite, mica, shell fragments, no microfossils. *Sample G12.*

Washed: Partly indurated, required some crushing; quartz, some glauconite, mica, many shell fragments, Foraminifera, ostracodes, many ostracodes rust-colored, partly filled with limonite. *Sample G11.*

Piscataway member "Dark-colored greensand; fossils very poorly preserved . . . 14 feet." Beds have higher clay content than above; water seeps from contact. This very irregular zone may mark weathered surface of this member.

Field: Dark-green glauconitic quartz sand, 4 to 10 feet thick. Mottled with limonite streaks which mark impressions of fossils; only few actual shells remain. Near top of zone was irregular, discontinuous indurated band 6 to 12 inches thick. *Samples G8 to 10.*

Washed: Quartz, some glauconite, mica, limonite, no calcite, unfossiliferous.

Field: Dark-green glauconitic, quartz sand, with bands of megafossils. Thickness varied greatly, depending on thickness of overlying zone. *Sample G7.*

Washed: Quartz, glauconite, mica, few worn shell fragments, mostly very fine; sparse microfauna; Foraminifera worn and broken.

"Indurated layer; *Turritella mortoni;* 1 foot."

Field: Light- to dark-gray fossiliferous indurated zone of variable width, probably source of large gray fossiliferous slumped blocks. *Sample G6.*

Washed and crushed: Mostly quartz, glauconite and shell fragments cemented with calcareous material; many Foraminifera and ostracodes.

"Zone of broken shells, 3 feet"; "Indurated layer, 6 inches"; "Greensand with broken shells, 6 inches."

Field: Very fossiliferous dark-green glauconitic marly sand, indurated layer discontinuous. *Sample G5* channeled from whole zone.

Washed: Quartz, glauconite, mica, many shell fragments, protoconchs and prodissoconchs, Foraminifera and ostracodes.

"Indurated layer. 1 foot."

Field: Light- to dark-gray, very fossiliferous, indurated greensand. *Sample G4.*

Washed and crushed: Quartz, glauconite, mica, calcareous-cemented pieces, many shell fragments, no microfossils.

"Dark-colored greensand with broken shells. 9 feet."

Field: Gray-green to black where exposed, dark-green where fresh. Upper two-thirds abundantly fossiliferous, fewer shells in lower 2 to 3 feet. Shells very white, crumbly; mostly oriented horizontally. Some pelecypods were apparently centers from which iron in glauconite was changing to limonite. *Samples G1 to 3.*

Washed: Mostly quartz, glauconite, mica, many shell fragments, many Foraminifera,

fewer ostracodes, sharks tooth, material fine. *Sample G3* from top.

Washed: Quartz, abundant glauconite, mica, many shell fragments, Foraminifera, few worn ostracodes. *Sample G2* from middle.

Washed: Abundant glauconite; quartz, mica, shell fragments, sharks teeth, few Foraminifera and ostracodes. *Sample G1* from base.

TAXONOMIC AND MORPHOLOGIC PROBLEMS

The taxonomic interpretation of fossil forms has suffered from lack of correlation with biological evidence, as is well known. This is especially true of the Ostracoda, which are classified mainly from living forms. The classification of ostracodes by G. O. Sars, and others, is based primarily on the soft parts, and the carapace has been given only incidental description.

Two problems in particular, which are of great importance to paleontologists, can be solved only by a thorough study of living forms. They are concerned with reproduction, and ontogenetic development or the molting of the carapace. Neither of these problems can be solved from paleontologic evidence alone, and until the paleontologist becomes more familiar with the biology and ecology of living species his conclusions will necessarily be of questionable value.

There are too few papers published on the ecology of Recent Ostracoda. However, the author has received much valuable help from Dr. W. L. Tressler, a biologist, formerly with the University of Maryland, and from an unpublished manuscript by E. M. Smith (1946), a student of Dr. Tressler. The author also spent a short time at the Chesapeake Biological Laboratory at Solomons, Maryland. It is difficult to make any statement regarding the conditions under which the fossil genera lived. Most present-day species are strictly bottom-dwellers, and many are incapable of swimming. Two suborders of Sars' classification are referred to in this paper. One of them, the Platycopa, is composed mainly of benthonic forms confined to the deeper parts of the ocean, and the other, the Podocopa, of either pelagic or benthonic forms, which are also adapted to bottom-dwelling.

Syngamy is the general rule in the reproduction of Ostracoda. The male carapace differs from that of the female in being more elongate, thinner, and having a smaller ratio of height to length. Females have more tumid shells, with a greater ratio of height to length, and in some genera the valves are more highly arched dorsally. This sexual dimorphism has been recognized and demonstrated in many Mesozoic and Tertiary forms, as well as in some Paleozoic genera. Some species of Recent Ostracoda reproduce parthenogenetically, or may be parthenogenetic only in some localities, and the males of some species are rarely found. This situation is also duplicated in paleontology.

In common with other crustaceans, ostracodes grow ontogenetically by successive molting of the carapace. The suborder Podocopa, to which most of the forms herein described are referred, are reported by several authors to have nine instars. However, no study has been made of molt carapaces of living forms. Several paleontologists have discussed the problem of molts, and C. L. Cooper (1945) and L. W. LeRoy (1945) have made studies of fossils molts of the genera *Ectodemites* from the Pennsylvanian and *Cythereis* from the Miocene and Pliocene. M. B. Stephenson (1946) has given an excellent summation of the work done to date. Certainly, wherever the relationship can be demonstrated, molts should be identified with the adult, but a paleontologist may find it very difficult to be sure of these relationships.

During this study, a number of molts have been found. Where evidence was believed sufficient, they are identified and illustrated with the adults. Some problems arose, however, in regard to the genus *Cythereis*. Several distinct species are present, and in some cases, as *Cythereis communis*, *Cythereis communis* var. *aquia*, and *Cythereis pauca*, evolutionary development supported by chronogenesis can be demonstrated. However, immature forms also occur. Some have the hinge, outline, and other characteristics of *Archicythereis*, as defined by Howe. Other specimens which also appear to be molts have the characters of *Paracythereis*. The ornamentation of specimens referred to "*Archicythereis*" is quite distinctive, and one form described as "*Archicythereis*" *retiplana* Schmidt n. sp. was found at three localities. This form does not appear to be a molt allied to any of the mature species with which it is associated. *Cythereis*

siegristae Schmidt n. sp. occurs at the same localities, but there is little resemblance. "*Archicythereis*" cf. *Cythereis pidgeoni* on the other hand, is probably a molt of *Cythereis pidgeoni*, and for that reason is tentatively referred to it. (No connecting instars have been found.) Both are very distinctively and unusually ornamented, but are easily separated on basis of outline, hinge, and nature of shells.

The pyriform, delicate specimens, described by Howe as *Archicythereis*, cause a problem which has been discussed with both paleontologists and biologists. LeRoy, and later Stephenson, have suggested that the use of *Archicythereis* be discontinued, and that such specimens be identified with the adult forms of *Cythereis*. If shells of the "*Archicythereis*" type are found associated with a single species of *Cythereis*, together with intermediate molts, their relations ordinarily will be evident, but if more than one mature species is recognized, can the corresponding molts be distinguished? Even if the later molts possess characters making their assignment to known species possible, probably the first few molts of closely related species would be identical.

Several adult forms of *Cythereis* are present in the studied material, but there are very few molts, which is not surprising because such delicate shells would be easily destroyed. Among the latter, those which are described as "*Archicythereis*" *retiplana* Schmidt n. sp. cannot be identified with any known species of *Cythereis* but seem worthy of recognition. Even though the name *Archicythereis* is a synonym (based on larval forms) it appears to be useful in a situation of this kind. By employing it in quotation two facts can be made apparent: (1) the specimens are believed to be immature molts, and (2) they are believed to represent some species of *Cythereis*. If it is believed they represent a particular species, but conclusive proof is lacking, they can be compared with that species.

In 1936, Jennings proposed the genus *Paracythereis* to accommodate forms which differ from *Cythereis* only in hinge structure. He described a single species and no others have been since recorded. M. B. Stephenson (1946, p. 305) found no specimens in type material sent him by Coryell, which is not surprising because the material is not abundantly fossiliferous. Some specimens in the present collections however, can be identified as *Paracythereis*, and have been compared and checked with the genotype at Columbia University by Coryell.

The specimens of *Paracythereis plusculmenis* Schmidt n. sp. from Maryland appear to be late molt stages of *Cythereis plusculmenis* Schmidt n. sp. The hinge, however, is not the same as any described by LeRoy in his molt studies. He mentioned only seven instars, whereas biologists record nine. This number is most likely variable. Probably *Paracythereis* is a late molt stage, but this cannot yet be proved. Should it be demonstrated, on the basis of Recent shells, where a complete series of molts of one species can be obtained, that the hinge of *Paracythereis* is identical with a certain molt stage of *Cythereis*, the name *Paracythereis* will become a synonym of *Cythereis*.

A problem has risen also with regard to the hinge structure of certain Cretaceous ostracodes that have been assigned to *Cytheridea*. This genus was proposed in 1852 by Bosquet. In 1929, C. I. Alexander described several ostracodes which he identified as *Cytheridea*, and in 1933, with C. W. Alexander, he presented a detailed description of the hinge structure of *C. plummeri* and *C. insolita*. The same description was repeated for *C. globosa* in the same year (Alexander 1933, p. 189). Stephenson in 1936 subdivided *Cytheridea* and in addition to the subgenus *Cytheridea*, proposed two new subgenera, *Haplocytheridea* and *Clithrocytheridea*. He recorded their ranges as Cretaceous to Recent and Eocene to Miocene respectively. Stephenson stated (1936, p. 698) that the description of the hinge structure given by Alexander (1933, p. 189) for *Cytheridea* should be considered "typical for the subgenus *Haplocytheridea* but distinct from and simpler than the hinge of the genotype" of *Cytheridea*. In 1941 he widened his description of *Haplocytheridea*, and included in it other later subgenera which he then recognized as molts (Stephenson 1941, pp. 424–429). Subsequently, these two subgenera have been raised to generic rank, and *Cytheridea* has been restricted.

Among the Eocene specimens from the

Atlantic Coastal Plain there are readily identifiable representatives of *Clithrocytheridea* and *Haplocytheridea*. Certain species originally assigned to *Cytheridea* from the Cretaceous, however, are difficult to assign. In *Haplocytheridea punctura*, a new species from the Marshalltown, and *Haplocytheridea pinochii* (Jennings) from the Mount Laurel, the hingement is correct for *Haplocytheridea* except that the lowermost crenulated groove is missing in the left valve. This condition might possibly represent an early phylogenetic stage. Six species from the Monmouth formation, one found in the Mount Laurel as well, have slightly different dentition. Most of these are identified as species previously described by Alexander from the Cretaceous of Texas.

Omitting from this discussion the matter of reversal of hinge structure, which has been noted in these forms, the hingement of these genera is briefly as follows:

Clithrocytheridea: Right valve: terminal notched cusps, connected by crenulated groove, or T G T.

Left valve: terminal notched sockets connected by elevated crenulated bar, or S B S.

Haplocytheridea: Right valve: terminal notched cusps connected by elevated row of crenulations above which is depressed furrow and then the dorsal margin, or $\overset{G}{TBT}$.

Left valve: terminal notched sockets connected by crenulated groove or S G S.

Cytheridea as described by Alexander (1933): *Right valve:* terminal elongate notched cusps connected by narrow crenulated bar, or T B T. *Left valve:* terminal notched sockets connected dorsally by narrow bar, separated from dorsal margin by groove or furrow; below bar is pitted groove which also connects sockets, or $\overset{G}{SBS}$. The dorsal bar and groove may be very distinct in strongly arched specimens and somewhat obscure in elongate, weakly arched specimens.

The Atlantic Coastal species in question agree with *Haplocytheridea* in other generic features such as the muscle-scar pattern, but the hinge is somewhat different from any of those noted above. The left valve has terminal notched sockets, connected by a raised crenulated bar and separated from the dorsal margin by an elongate deep groove $\overset{G}{SBS}$. The lowermost groove, described by Alexander as connecting the sockets, has not been noted. If there were no other differences, this might be interpreted as a matter of development (as is done for *H. punctura* Schmidt, and *H. pinochii* (Jennings)), or individual variation. However, the right valve has terminal raised notched cusps connected by a narrow crenulated groove, and in some the dorsal margin overlaps the groove or T G T. This is the "formula" for *Clithrocytheridea*, not *Haplocytheridea*. These species occur in the Cretaceous, whence *Clithrocytheridea* has not yet been reported. They probably do not belong to that genus, but seem to be a variant of *Haplocytheridea*, and perhaps should be recognized as a new subgenus.

METHODS OF EXAMINATION

All samples were examined under the microscope before washing and, if indurated, were crushed with mortar and pestle. The material was soaked in a sodium peroxide solution to break down the clay, then washed and dried. The use of heavy liquids, such as bromoform, carbon tetrachloride or other decanting methods was not very successful in separating the microfauna, as many of the shells were filled with glauconite or clay.

In very glauconitic samples rapid separation of fossils from glauconite was obtained by a magnetic method. The washed sample was screened and most coarse glauconite removed with a large electromagnet. The fossiliferous residue was still further refined by the Frantz isodynamic separator and within thirty minutes a sample was ready for picking. Material remaining on the 50 to 110 mesh screens was used, the smaller sizes being most successfully separated by this method. A current of 1.2 amperes, a tilt of 2½ degrees toward the magnetic side, and inclination toward the collecting tins dependent on the grain size, produced the best results. This method is an excellent timesaver in highly glauconitic samples, and the separation is good.

CONCLUSIONS

The Upper Cretaceous and the basal Eocene formations are lithologically similar at many places but they are easily distinguishable by their ostracodes. Twenty-four species have been found in the Aquia formation, and 27 other species occur in the Upper Cretaceous formations. The subdivision of the Aquia formation into the Piscataway and Paspotansa members cannot be made on the basis of ostracodes but formations of the Upper Cretaceous series are easily distinguished. Five species are common to the Marshalltown and Mount Laurel formations, but only one has been found in both the Mount Laurel and Monmouth. Previously described ostracodes identified in the collections support correlations of the Aquia formation with the Hornerstown marl of New Jersey and the Wilcox group of the Gulf Coast; and of the Monmouth formation with the Navarro group of the the Gulf Coast.

Most of the Ostracoda described in this paper belong to the suborder Podocopa, in which the living forms, either pelagic or benthonic, are adapted to a bottom-dwelling existence. Problems of the ontogenetic development of ostracodes by molting are discussed, particularly with regard to early molts of *Cythereis*. *Paracythereis* might possibly be a late molt stage of *Cythereis*. Certain Monmouth ostracodes assigned questionably to *Haplocytheridea* differ slightly but consistently in dentition from the generic description.

PALEONTOLOGY

The types of the Monmouth Ostracoda described by E. Willard Berry, according to a personal communication (August, 1946) were deposited at Johns Hopkins University, and were last seen there by the original author "20 years ago." An extensive search there and at the U. S. National Museum has revealed no trace of them. The original descriptions are very brief, the orientation of the carapaces is inconsistent, and the illustrations are not as good as could be desired. No locality, other than Brightseat, Md. is given, and the outcrop, also mentioned in the Maryland Cretaceous volumes (Clark and others, 1916), has not been found up to January, 1947. Professor Harold E. Vokes of Johns Hopkins University gave the author some topotype material that was found at the University. Many of Berry's species have been identified in this sample, and these topotypes are described and illustrated. Jennings' holotypes are at Columbia University.

All types of the present paper are at the U. S. National Museum.

Literature reaching the author after January 15, 1947 was not considered in the preparation of this report.

SYSTEMATIC DESCRIPTIONS

Order OSTRACODA Latreille
Suborder PLATYCOPA Sars
Family CYTHERELLIDAE Sars, 1865
Genus CYTHERELLA Jones, 1849

Genotype: *Cytherina ovata* Roemer, 1840.

CYTHERELLA OVATA (F. A. Roemer)
Plate 61, figure 3

Cytherina ovata F. A. ROEMER, 1840, Verstein. norddeutsch. Kreidegeb., p. 104, pl. 16, fig. 21.
Cytherina complanata REUSS, 1845, Verstein, böhm. Kreideform., pt. 1, p. 16, pl. 4, fig. 35.
Cythere reniformis BOSQUET, 1847. Mém. Soc. Roy. Sci. Liège, vol. 4, p. 356, pl. 1, figs. 1a–f.
Cytherella ovata, JONES, 1849, Monogr. Entom. Cret. England, Paleontogr. Soc. London, p. 28, pl. 7, figs. 24a–i.
Cytherella complanata, REUSS, 1854, Denkschr. K. Akad. Wiss., Wien vol. 7, p. 140, pl. 28, fig. 9.
Cytherella ovata ALEXANDER, 1929, Texas Univ. Bull. 2907, pp. 47–48, pl. 1, figs. 1, 2.

Dimensions.—Right valve, length, 0.73 mm.; height, 0.51 mm.; thickness, 0.23 mm.

Hypotype.—U. S. National Museum 104179, from sample (A1).

Occurrence.—Common in the Marshalltown formation of Delaware (A1). Alexander recorded this as common in the upper and middle parts of the Goodland and rare in the Kiamichi of Texas.

Remarks.—Other specimens of *Cytherella* occur in succeeding formations, but none can be identified as this species. *C. ovata* might possibly be the female of an elongate *Cytherella*. Only single valves were found. These were compared with specimens of Jones' at the U. S. National Museum, from the Chalk marl of England and found to be identical.

CYTHERELLA cf. BEYRICHI (Reuss)
Plate 61, figure 2

Cytherella beyrichi (Reuss) 1851. JONES and SHERBORN, Sup. Mon. Tert. Entom. England Pal. Soc. London pt. 4, 1890, p. 48, pl. 2, figs. 5–7.

Description.—Carapace in side view oblong, in dorsal view lanceolate, widest posteriorly. Right valve overlaps left valve on all margins, more so dorsally. A median sulcus is present extending from dorsal margin to center of valve. Surface of valves minutely punctate.

Dimensions.—Complete specimen, length, 0.60 mm.; height, 0.36 mm.; thickness, 0.26 mm.

Hypotype.—U. S. National Museum 104180, from sample A1, Marshalltown formation.

Occurrence.—Rare in the Marshalltown formation (A1), and in the Monmouth formation at Brightseat, Md. Doubtful specimens from samples B4 and G14.

Remarks.—This is distinguished from most other species of *Cytherella* by its punctate surface. It is compared with *C. beyrichi* (Reuss) as illustrated by Jones and Sherborn but it is not certainly identified as this species, because of the age difference. It is not referred to *C. muensteri* (Roemer) because of the presence of a median sulcus, and the general roundness of the shell. Two punctate forms occur in the Aquia formation but they lack a median sulcus.

CYTHERELLA spp.
Plate 61, figures 4–6

Smooth specimens of *Cytherella* occur from the Marshalltown through the Aquia formations, but not abundantly. Only one valve was found in the Mount Laurel sand, and that was broken. No attempt was made to identify these smooth forms. Long narrow specimens, probably male, occur more frequently than more ovate shells, which are probably female. The specimens illustrated are typical complete carapaces and show most of the overlap, although valves of the female specimen separated before photographs were taken. There is no noticeable difference between the Cretaceous and Eocene forms. Some small thin broken valves were found which might be molts.

Dimensions.—Male, complete specimen, length, 0.75 mm.; height, 0.45 mm.; thickness, 0.33 mm. Female, left valve, length, 0.75 mm.; height, 0.45 mm.; thickness, 0.20 mm.; right valve, length, 0.79 mm.; height, 0.51 mm.; thickness, 0.21 mm.

Hypotypes.—U. S. National Museum 104181 (male), 104182 (female), from samples F5 and G11 respectively, Aquia formation.

Occurrence.—Male: Marshalltown (A1), Monmouth (E3, Brightseat), Aquia (B5, 6, E5, F5, G5, 6); female: Marshalltown (A1), Aquia (B6, C3, E5, G11).

Genus CYTHERELLOIDEA Alexander, 1929
Genotype: *Cytherella williamsoniana* Jones, 1849.

CYTHERELLOIDEA SPIRALIA Jennings
Plate 61, figure 1

Cytherelloidea spiralia JENNINGS 1936. Bull. Am. Paleontology vol. 23, no. 78, p. 42, pl.6, fig. 2.

Original description.—Carapace compressed, small, inequivalved, subovate in lateral view; dorsal margin gently arched; anterior margin broadly rounded; ventral margin slightly concave; posterior margin less broadly rounded than anterior.

On the right valve a marginal ridge starts at the posterior dorsal contact, and running anteriorly, passes round the dorsal, anterior, ventral, and posterior margins; on reaching the posterior dorsal angle the ridge curves inwards and extends in an anterior direction within the marginal ridge, dying out in the anterior dorsal region. A broad shallow pit is located dorsally to the center; posteriorly the pit narrows and joins the groove extending around the carapace inside the marginal ridge; just ventral to the center a shallow groove parallels the ventral border which is succeeded ventrally by a low ridge which is terminated by and separated from the marginal ridge by the marginal groove.

The left valve differs from the right in that the marginal ridge starts at the anterior dorsal contact instead of the posterior dorsal contact and, extending round the anterior ventral and posterior margins, curves inward at the posterior dorsal angle and passes anteriorly along the hinge margin terminating near the anterior dorsal contact. The right valve is larger than the left. The overlap consists only of that part of the marginal ridge that extends from the anterior to the posterior dorsal contact. Length 0.53 mm.; height, 0.31 mm.; thickness, 0.16 mm.

Mt. Laurel and Navesink. Columbia University Coll. No. M19.

Dimensions.—Complete specimen, length, 0.50 mm.; height, 0.29 mm.; thickness, 0.17 mm.

Hypotype.—U. S. National Museum 104183, from sample A1.

Occurrence.—Rare in the Marshalltown (A1) and Mount Laurel (A2) formations.

Remarks.—One left valve, subsequently broken, was found in the Mount Laurel sand, and a smaller complete carapace which agrees with the holotype, in the Marshalltown formation.

CYTHERELLOIDEA MONMOUTHENSIS
Jennings 1936
Plate 61, figure 7

Cytherelloidea monmouthensis JENNINGS 1936. Bull. Am. Paleontology vol. 23, no. 78, p. 41, pl. 6 fig. 4.

Original description.—Carapace small, compressed, oblong, ovate in lateral view; dorsal [ventral] margin straight; anterior margin broadly rounded; ventral [dorsal] margin gently convex to almost straight; posterior margin more narrowly rounded than anterior.

A narrow ridge parallels the entire margin; it is most strongly developed on the anterior margin, and is well developed on the dorsal [ventral] and posterior margins; on the ventral [dorsal] margin the development of the ridge weakens from the anterior towards the posterior margins until it almost disappears at the posterior ventral [dorsal] contact. Two ridges emerge from the curvature of the valves, one opposite the antero-ventral [-dorsal] contact and another opposite the antero-dorsal [-ventral], and each extends posteriorly parallel to its adjacent dorsal or ventral margins and close to the marginal ridge; the dorsal [ventral] ridge merges with the curvature of the valve and the ventral [dorsal] ridge ends in a tubercle. A broad shallow pit is located just ventral [dorsal] to the center of the valves between the two inner ridges, and is so close to the ventral [dorsal] one of these that it appears to bend around it. Length 0.47 mm.; height, 0.30 mm.; thickness, 0.18 mm.

This form differs from *C. williamsoniana* in having but one tubercle and a complete marginal ridge.

Navesink. Columbia University Coll. No. M17.

Dimensions.—Right valve, length, 0.51 mm.; height, 0.32 mm.; thickness, 0.09 ± mm.

Hypotype.—U. S. National Museum 104184, from sample A2.

Occurrence.—Common in the Mount Laurel formation (A2).

Remarks.—Jennings illustrated a right valve, which was incorrectly oriented. He referred to it as a left valve on the plate explanation and his description refers to a left valve with the words dorsal and ventral interchanged. The specimens from Delaware in this collection agree with Jennings' description when corrected, and with the holotype.

A feature not mentioned in the original description, but present both on the holotype and on the present specimens, are small "depressions" arranged in a row just dorsal to the ventral ridge. In one specimen the tubercle at the posterior dorsal angle merges with the anterior margin.

CYTHERELLOIDEA TRUNCATA
Schmidt, n. sp.
Plate 63, figure 25

Description.—Carapace oblong ovate in side view. Dorsal margin convex, slightly sinuate anteriorly. Ventral margin straight. Anterior and posterior ends rounded, posterior end somewhat elevated and truncate. A broad marginal rim starts at anterior dorsal contact, follows anterior and ventral margins, dying out at truncated posterior end. A fainter ridge is present along dorsal margin. A prominent high ridge starts at posterior ventral contact, curves broadly around posterior dorsal contact, where it is highest, and after short distance bifurcates into low broader ridges which surround a low subcircular central pit or depression. The upper ridge ends below and posterior to anterior dorsal contact; the lower ridge is slightly longer and dies out on anterior third of shell. Below the lower ridge and parallel to ventral margin is a sharper high ridge. Surface otherwise smooth. Hinge simple, consists of groove in right valve.

Dimensions.—Right valve only, length, 0.56 mm.; height, 0.33 mm.; thickness, 0.10 mm.

Holotype.—U. S. National Museum 104185, from sample G5.

Occurrence.—Rare in the Aquia formation (B5, G6, 7).

CYTHERELLOIDEA spp.

Other specimens of *Cytherelloidea* were found but they are too poorly preserved for accurate identification. Small, thin, delicate valves that seemed to be molts of some species of this genus occur in Marshalltown and Mount Laurel formations.

Suborder PODOCOPA Sars
Family CYPRIDAE Baird, 1846
Genus PARACYPRIS Sars, 1865

Genotype: *Paracypris polita* Sars, 1865.

Carapace in side view, long, narrow. Rounded

anteriorly, produced and tapering to an acute angle posteriorly. Valves subequal, the left being slightly larger than the right. Shell compressed, in dorsal view lanceolate; ends acute to subacute. Hinge simple.

Marginal zone of shell narrow, pore-canals few in number and widely spaced, straight and simple. Inner margin parallel to, but at considerable distance from, line of concrescence at anterior and posterior ends, coinciding with it for a short distance along the anterior one-third of the ventral margin.

Muscle-scar area roughly circular, near center of valves. Muscle scars in genotype, six in number. A long narrow scar is situated at the top of the muscle-scar area, and the other five scars form two vertical rows, three scars in the anterior row and two in the posterior.

—Alexander, 1934 p. 214

PARACYPRIS STRECCA Schmidt, n. sp.
Plate 63, figures 21, 22

Description.—Carapace elongate in side view, highest just behind anterior cardinal angle, tapering strongly posteriorly. Left valve overlaps right on all margins. Dorsal margin gently arched, ventral margin straight, slightly sinuous in center. Anterior margin bluntly rounded, posterior margin acute. Surface smooth. Internal characters typical of the genus.

Dimensions.—Complete specimen, length, 0.94 mm.; height, 0.38 mm.; thickness, 0.25 mm.

Holotype.—U. S. National Museum 104186, from sample G14.

Occurrence.—Rare in the Aquia formation (G14 and G5).

Remarks.—This species differs from others previously described, in outline of dorsal margin, and location of the highest point just behind the anterior cardinal angle combined with straight ventral edge.

PARACYPRIS MONMOUTHENSIS
Schmidt, n. sp.
Plate 62, figure 17

Description.—Carapace elongate in side view, greatest height just anterior of center. Dorsal margin gently and evenly arched, but slopes abruptly posteriorly. Ventral margin straight. Anterior end broadly and bluntly rounded, posterior end acute, almost a right angle. Surface smooth. Internal characters typical of the genus.

Dimensions.—Left valve, length, 0.76 mm.; height, 0.30 mm.; thickness, 0.13 mm.

Holotype.—U. S. National Museum 104187, from sample E3.

Occurrence.—Rare in the Monmouth formation (E3).

Remarks.—This specimen differs from *P. strecca* in outline. It is more like *P. dentonensis* Alexander 1929 from the Duck Creek limestone of Texas; but the ventral margin is straight, and the dorsal margin more evenly arched.

PARACYPRIS sp.

A specimen of *Paracypris* was found in Marshalltown material. The dorsal margin was broken, and no attempt was made to identify it further.

Family BAIRDIIDAE Sars, 1887
Genus BAIRDOPPILATA Coryell, Sample, and Jennings, 1935

Genotype: *Bairdoppilata martyni* Coryell, Sample, and Jennings, 1935.

BAIRDOPPILATA PONDERA Jennings
Plate 61, figures 21, 22

Bairdoppilata pondera JENNINGS 1936. Bull. Am. Paleontology vol. 23, no. 78, p. 45, pl. 6, fig. 9.

Original Description.—Test large, inequivalved, subtriangular in lateral view; dorsal margin strongly arched; anterior margin broadly and obliquely rounded; ventral margin convex; posterior margin obtusely angulated. Left valve overlaps the right over the entire margin, overlap stronger on the dorsal and ventral margins. Greatest height central; greatest length slightly ventral of center; greatest thickness central. Hingement typical of the genus. Length, 1.15 mm.; height, 0.82 mm.; thickness, 0.70 mm.

This form resembles *Bairdoppilata magna* (Alexander) but has longer ventral and postal slopes and a stronger dorsal overlap.

Navesink and Mount Laurel. Columbia University Coll. No. M32.

The muscle-scar pattern, which is difficult to see in most specimens, consists of about ten scars, seven large ones, irregularly disposed, and three smaller ones.

Dimensions.—Left valve, length, 1.19 mm.; height, 0.79 mm.; thickness, 0.45 mm.; right valve, length, 1.29 mm.; height, 0.79 mm.; thickness, 0.41 mm.

Hypotypes.—U. S. National Museum 104188 a, b, from sample A2.

Occurrence.—Very abundant in the Mount Laurel sand (A2).

Remarks.—Most specimens have smooth surfaces. They agree with the holotype.

BAIRDOPPILATA spp.

Some specimens of this genus, which differed from *B. pondera*, were found in the Marshalltown formation. They are neither sufficiently abundant nor well enough preserved to warrant description.

Genus BYTHOCYPRIS Brady, 1880

Genotype: *Bythocypris reniformis* Brady, 1880.

BYTHOCYPRIS PARILIS Ulrich
Plate 63, figures 14–16

Bythocypris parilis ULRICH 1901. Maryland Geol. Survey, Eocene volume, p. 117, pl. 16, figs. 5–8.
Bythocypris parilis JENNINGS 1936. Bull. Am. Paleontology, vol. 23, no. 78, p. 45, pl. 6, fig. 8.

Description.—Carapace reniform in side view. Dorsal margin strongly arched, ventral margin slightly convex. Both ends rounded, and very nearly equal; posterior end slightly more oblique dorsally. Left valve overlaps right, more so dorsally and ventrally than at ends. Surface generally smooth, but many specimens when wet show very small punctae. Marginal area wide, more so anteriorly than posteriorly. Posterior marginal area forms acute angle, anterior marginal area rounded.

Dimensions.—Left valve, length, 0.75 mm.; height, 0.35 mm.; right valve, length, 0.71 mm.; height, 0.35 mm.; thickness of complete specimen, 0.30 mm.

Hypotypes.—U. S. National Museum 104189 a, b, from sample G6.

Occurrence.—Common in the Aquia formation (B6, C2, E5, G5, 6, 11, 14). Ulrich described this species from Upper Marlboro, Md. and Jennings reported it from Hornerstown at New Egypt, N. J.

Remarks.—The specimens were compared with Ulrich's types at the U. S. National Museum.

Family CYTHERIDAE Baird, 1850
Genus KRITHE Brady, Crosskey and Robertson, 1874

Genotype: *Cytherideis bartonensis* Jones 1857.

Carapace in side view oblong, highest at or slightly posterior to middle. Dorsal margin gently arched. Ventral margin straight or nearly so. Anterior end rounded. Posterior end obliquely truncated, with subacute, rounded, postero-ventral angle. In dorsal view, carapace varies from moderately to strongly convex; anterior end acute to subacute, posterior end blunt, incised at middle. Surface, mooth, or rarely obscurely punctate or papillate.

Hinge structure without teeth, consisting of a slight groove in the dorsal margin of the left valve, into which the dorsal edge of the right valve fits.

Line of concrescence extends vertically downward from the dorsal margin, at about one-fifth the length of the shell from the anterior end. In the lower half of the anterior end, it makes a broad, distally expanded loop which approaches very near to the outer margin of the shell, and a similar, narrower loop at the postero-ventral angle of the shell, but elsewhere it runs at a moderate distance from, and parallel to, the outer margin. Inner margin and line of concrescence coincide except where the latter makes its sharp looplike curves toward the outer margin at the anterior and posterior ends. Radial pore-canals moderately numerous, slender, with large external openings, often curved, and of very unequal length; many of the canals open on the exterior surface of the shell before reaching the outer margin. Normal canals few in number, large, conspicuous.

Muscle-scar pattern consists of a vertical row of four long, slender scars, with two others in front of these; the upper one of these two is large and roughly U-shaped, the lower one small, elongated and narrow.

Sexual dimorphism marked, the shells of the males being longer and more slender and less strongly convex than those of the females.

—Alexander, 1934, p. 229

KRITHE POSTPROJECTA Schmidt, n. sp.
Plate 61, figure 8; text figure 2d

Description.—Carapace oblong to rhomboidal in side view. Dorsal margin very gently arched, curving sharply downward posteriorly to form posterior margin. Ventral margin straight to imperceptibly convex. Anterior margin bluntly rounded, forming almost right-angled curve with dorsal margin, more rounded curve with ventral margin. Posterior margin produced in slight rounded projection at ventral margin, which distinguishes this from other forms. Surface smooth to obscurely punctate. Internal characters typical of genus.

Dimensions.—Left valve, length, 0.63 mm.; height, 0.27 mm.; thickness, 0.15 mm.

Holotype.—U. S. National Museum 104190 a, paratype, 104190 b, from sample A1.

Occurrence.—Common in the Marshalltown formation (A1).

Remarks.—This species closely resembles *Pseudocythere? simplex* Jones and Hinde 1890, p. 30, pl. 2, figs. 58–60, pl. 4, figs. 37, 38; but their figure 37 on pl. 4 of the interior shows no inner margin, whereas *K. postprojecta* has inner margin typical of this genus.

Genus XESTOLEBERIS Sars, 1865

Genotype: *Cythere aurantia* Baird 1838.

Carapace in side view ovate, highest at or distinctly behind middle. Dorsal margin arched. Ventral margin straight or slightly convex downward. Anterior end low, narrow, rounded or subacutely angled. Posterior end broadly rounded. Valves moderately to strongly convex, carapace widest and rounded tumid posteriorly. Surface smooth, or in some species finely punctate or papillate.

Hinge structure of the right valve consists of a finely denticulate anterior ridge that occupies nearly half the length of the hinge margin, a posterior tooth that bears numerous small cusps, and between the ridge and the tooth, a long, narrow, shallow, notched furrow or groove. The left valve bears a long, narrow, notched anterior groove, a small posterior socket, and an intermediate denticulate ridge or bar.

Line of concrescence very near, and parallel to, the outer margin of the shell around the entire periphery. Inner margin and line of concrescence coincide except at the anterior end, where the course of the inner margin is at a considerable distance within that of the line of concrescence, but is still roughly parallel to the outer margin, and along the posteroventral region where the inner margin lies at a slight distance within the line of concrescence. Radial pore-canals numerous, closely spaced, rather large, straight, simple.

Muscle-scar pattern consists of a vertical row of four long narrow scars, with a single larger, U-shaped scar in front of these.

—Alexander, 1934, p. 232

XESTOLEBERIS OPINA Schmidt, n. sp.
Plate 61, figures 15, 16; text figure 2b

Description.—Carapace in side view subtriangular, highest in center or just posterior to center; obovate in dorsal view; almost straight at posterior end, which is tumid. Dorsal margin strongly arched. Ventral margin straight to slightly convex. Anterior margin more oblique dorsally than posterior margin, which is rounded and continuous with curvature of ventral margin. Anterior margin forms subacute angle with ventral margin. Surface smooth. Internal characters typical of genus.

Dimensions.—Left valve, length, 0.48 mm.; height, 0.33 mm.; thickness 0.15 mm.; right valve, length, 0.46 mm.; height, 0.32 mm.; thickness, 0.13 mm.

Cotypes.—U. S. National Museum No. 104191 a, left valve; 104191 b, right valve, from sample A1.

Occurrence.—Abundant in the Marshalltown formation (A1), rare in the Mount Laurel sand (A2).

Remarks.—Some small fragile shells which may be molts also occur in Marshalltown material. This species differs in posterior and dorsal outline from *X. truncata* Alexander, which it otherwise resembles.

XESTOLEBERIS MAYERI (Howe and Garrett)
Plate 63, figure 10; text figure 2a

Bythocypris? mayeri HOWE and GARRETT 1934. Louisiana Dept. Cons. Geol. Bull. 4, p. 29, pl. 1, figs. 8–10.

Description.—Carapace in dorsal view elongate, obovate, widest posteriorly, in side view elongate-ovate, highest posterior to middle. Dorsal margin gently arched, ventral margin slightly contracted in middle. Anterior margin narrowly rounded, compressed, faintly rimmed and denticulate, slightly produced ventrally. Posterior margin bluntly subacute, faintly rimmed and denticulate, slightly produced ventrally, oblique dorsally.

Surface rounded, finely reticulate, with a pore in each reticulation. Just anterior to the middle on the elongate male valves, and at the middle on the shorter plumper female valves, a deep narrow trench leaves the dorsal margin, trending diagonally toward the anterior end, until it reaches the central axis of the carapace, where it bifurcates, partially surrounds a circular area of 'lucid spots' and disappears.

—Howe and Garrett, 1934, p. 29

Inner margin widens posteriorly. Hinge, muscle-scar pattern, radial pore-canals and other internal characters typical of genus.

Dimensions.—Left valve, length, 0.73 mm.; height, 0.26 mm.; thickness, 0.15 mm.

Hypotype.—U. S. National Museum No. 104192, from sample C3.

Occurrence.—Rare in the Aquia formation (C3, E5). Howe and Garrett record the species as rare in the Sabine group at Sabinetown, La., and Nanafalia, Ala.

Remarks.—This rare species was questionably referred to *Bythocypris* by Howe and Garrett. The internal characters are easily seen, however, and identify it as *Xestoleberis*. The elongate shape is unusual for this genus. *X. mayeri*, *X. longissima*, and possibly *Bythocypris? mcguirti* Howe and Garrett 1934, are the only elongate representatives of the genus known. It might be advisable to erect a subgenus for these elongate forms if additional species are identified.

XESTOLEBERIS LONGISSIMA
Schmidt, n. sp.
Plate 63, figures 11–13

Description.—Carapace in dorsal view elongate, obovate, widest posteriorly. In side view elongate-ovate to subrectangular, highest near center. Dorsal margin gently arched, ventral margin slightly contracted at middle. Anterior margin obliquely rounded, faintly rimmed and denticulate; posterior end bluntly rounded, faintly rimmed. Surface appears smooth, but is minutely punctate, giving granular appearance in some specimens; barely discernible lines subparallel or concentric with anterior margin. Region over muscle scar often worn giving false impression of sulcus. Internal characters typical of genus.

Dimensions.—Left valve, length, 0.76 mm.; height, 0.28 mm.; thickness of complete specimen, 0.28 mm.

Holotype.—U. S. National Museum 104193 a, paratype 104193 b, from sample B4.

Occurrence.—Common in the Aquia formation (B4, C2) at Oakgrove and Upper Marlboro. Ten specimens from sample B6 at Oakgrove have crystallized shells and are doubtfully assigned to this species.

Remarks.—See Remarks under *X. mayeri*.

Genus EUCYTHERE Brady, 1868

Genotype: *Cythere declivis* Norman 1865.

Shell in side view triangular in outline, highest at or near anterior end. Hinge margin straight or nearly so, ventral margin straight or slightly sinuate. Anterior end high, broadly rounded. Posterior end subacute to obtuse. Carapace usually widest behind middle.

The hinge structure is so weakly developed in most species that generic allocation is much more easily made on the basis of other shell structures.

The line of concrescence is at a moderate distance from, and parallel to, the outer margin of the shell. The inner margin is rather widely separated from the line of concrescence at the anterior end of the shell, but coincides with it elsewhere except for a very slight deviation at the posterior end. Radial pore-canals few in number, widely spaced, straight, narrow, simple. Normal pore-canals few in number, rather large and conspicuous.

—Alexander, 1936, p. 689

EUCYTHERE TRIORDINIS Schmidt, n. sp.
Plate 63, figures 26, 27, text figure 2c

Description.—Carapace triangular in side view, apex just anterior of center. Widest ventrally and centrally. Dorsal margin straight, but slopes steeply posteriorly. Anterior margin high and very broadly rounded, extends somewhat below ventral margin at anterior ventral angle. Ventral margin straight. Posterior margin narrow, bluntly rounded, forming almost a right angle in left valve, more acute in right valve. Posterior cardinal angle more pronounced in right valve. Surface of shell smooth. When wet about three widely spaced concentric rows of normal pore canals visible. Internal characters typical of genus.

Dimensions.—Left valve, length, 0.51 mm.; height, 0.31 mm.; thickness, 0.13 mm.; right valve, length, 0.48 mm.; height, 0.28 mm.; thickness, 0.13 mm.

Cotypes.—U. S. National Museum 104-194 a, b, from sample B4.

Occurrence.—Rare in the Aquia formation (B4).

Remarks.—Swain (unpub. mss.) has recognized a much higher species whose highest point is more anterior.

Genus MONOCERATINA Roth, 1928

Genotype: *Monoceratina ventrale* Roth 1928.

MONOCERATINA PEDATA (Marsson)
Plate 61, figure 10

Cythere pedata MARSSON 1880. Mittheil. naturwiss. Verein von Neu-Vorpommern und Rügen in Greifswald, p. 46, pl. 3, fig. 16c.

Cytheropteron pedatum, JONES and HINDE 1889. Suppl. Monogr. Cret. Entom. Engl., Irel., Paleontogr. Soc. London, p. 38, pl. 4, figs. 33–35.

Cytherura spooneri ISRAELSKY 1929. Arkansas Geol. Survey, Bull. 2, p. 6, pl. 4A, fig. 7.

Monoceratina pedata, ALEXANDER 1933. Jour. Paleontology, vol. 7, p. 203, pl. 27, fig. 15.

Monoceratina pedata, ALEXANDER 1934. Jour. Paleontology, vol. 8, p. 60.

Dimensions.—Left valve, length, 0.76 mm.; height, 0.41 mm.

Hypotype.—U. S. National Museum 104195, from sample A1.

Occurrence.—Rare in the Marshalltown formation (A1).

Israelsky recorded this species as rare in the Ozan and Marlbrook formations of Arkansas; Alexander recorded it as common in the Annona and Saratoga chalks of Arkansas, the Gober and Annona chalks of northeast Texas, and the lower two-thirds of the Taylor group of Texas.

MONOCERATINA BILOBA Schmidt, n. sp.
Plate 61, figure 9

Description.—Carapace rhomboidal in side view. Dorsal and ventral margins straight, parallel. At posterior end ventral margin curves broadly upward to posterior margin. Anterior margin broadly rounded. Posterior margin has slight caudal process in dorsal fourth, ventral three-fourths slant dorsally upward to meet caudal process. Faint rim around posterior margin. Ornamentation consists of two broad, bulging lobes, divided by distinct median sulcus. Ventral part of posterior lobe has bulbous node projecting outward and downward. A faint ridge starts below and in front of posterior cardinal angle, extending anteriorly, and around about midway up on anterior lobe, and ends at projecting node of posterior lobe. Surface finely pitted, giving a granular appearance. Hinge simple, consists of narrow bar in left valve. Right valve not found.

Dimensions.—Left valve, length, 0.51 mm.; height, 0.26 mm.; width, 0.23 mm. with bulbous projection, 0.15 mm. without.

Holotype.—U. S. National Museum 104196, sample A1.

Occurrence.—Rare in the Marshalltown formation (A1).

Remarks.—Resembles *Cythere umbonata* Jones (1849) but lacks a spine and differs in the bulbousness of posterior projections.

Genus LOXOCONCHA Sars, 1865

Genotype: *Loxoconcha bairdi* Müller 1912.

LOXOCONCHA CRETACEA Alexander
Plate 62, figure 7

Loxoconcha cretacea ALEXANDER 1936. Jour. Paleontology, vol. 10, p. 693, pl. 93, figs. 5, 7.

Dimensions.—Left valve, length, 0.50 mm.; height, 0.25 mm.

Hypotype.—U. S. National Museum 104197.

Occurrence.—Rare in the Monmouth formation at Brightseat, Md. Alexander recorded this species from lower Navarro clays of Texas.

Remarks.—Only one very well preserved left valve was found in the topotype material from Brightseat. It was broken before photographs were taken.

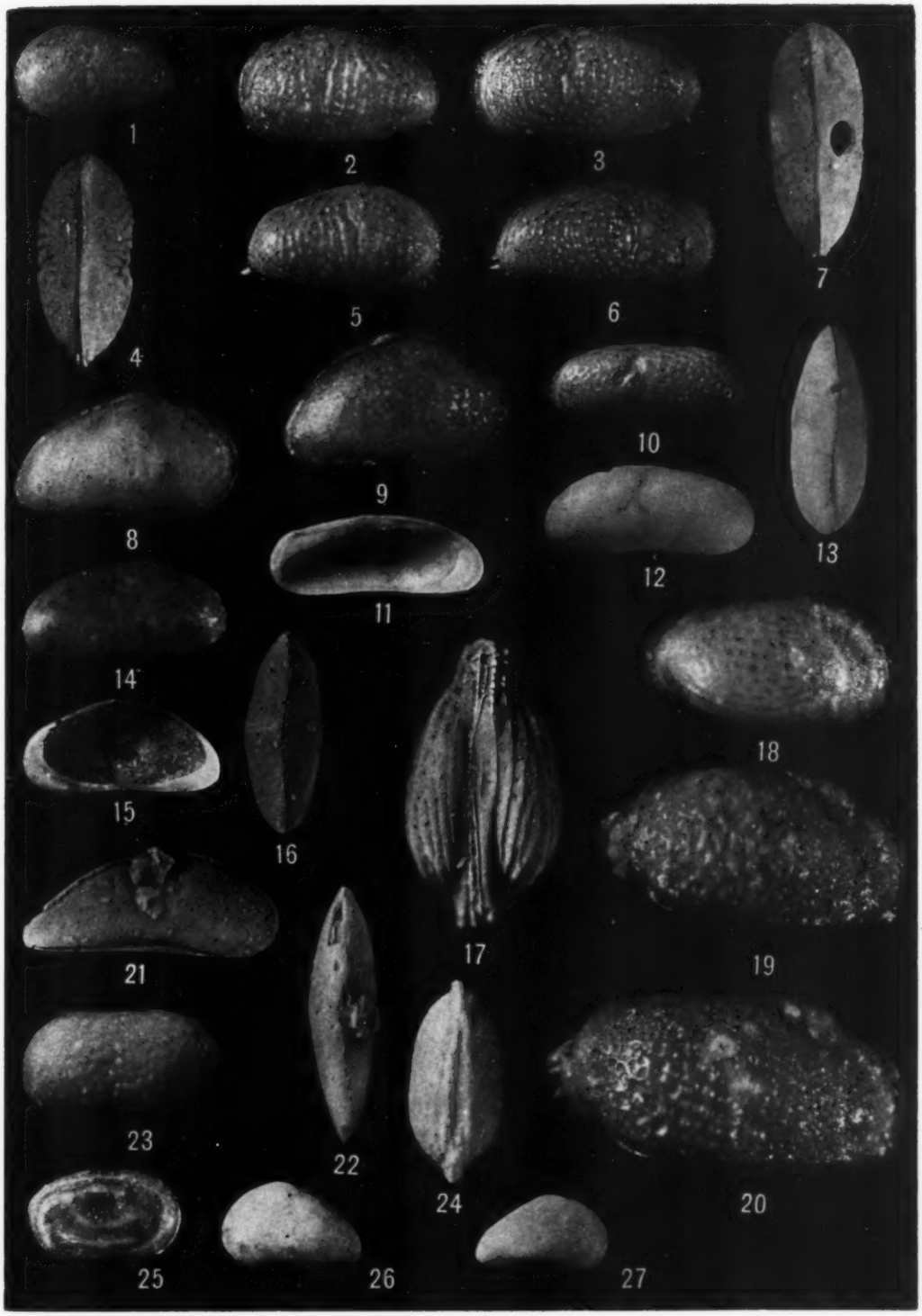
LOXOCONCHA? sp. Schmidt
Plate 63, figures 23, 24

Description.—Carapace quadrate in side

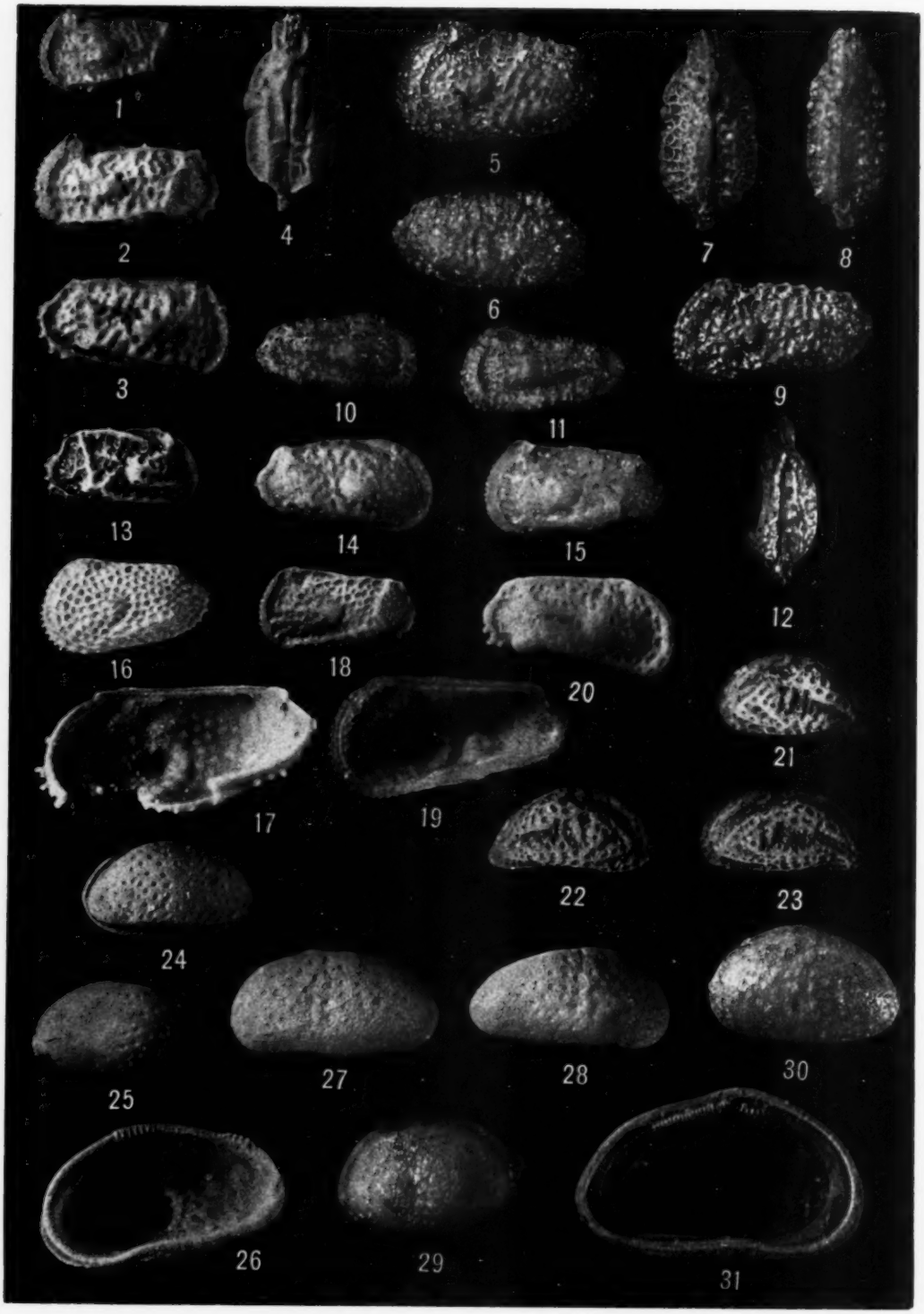
EXPLANATION OF PLATE 63

Figures ×40 unless otherwise indicated

FIGS. *1–7—Haplocytheridea veatchi aquia* Schmidt, n. var. *1*, left valve, molt. *2*, *4*, *5*, females; *3*, *6*, *7*, males. *2*, *3*, left valves; *5*, *6*, right valves; *4*, *7*, dorsal views, complete specimens. (p. 424)
8, *9—Haplocytheridea leei* (Howe and Garrett). *8*, right valve, male; *9*, right valve, female. (p. 424)
10—Xestoleberis mayeri (Howe and Garrett). Left valve. (p. 410)
11–13—Xestoleberis longissima Schmidt, n. sp. *11*, interior, left valve; *12*, left valve; *13*, dorsal view, complete specimen. (p. 411)
14–16—Bythocypris parilis Ulrich. *14*, right valve; *15*, interior, right-valve; *16*, dorsal view, complete specimen. (p. 409)
17–20—Brachycythere marylandica (Ulrich). *17*, ventral view, complete female specimen; *18*, right valve, molt; *19*, right valve, female; *20*, right valve, male. (p. 416)
21, *22—Paracypris strecca* Schmidt, n. sp. *21*, right valve, *22*, dorsal view; (piece of extra shell material present near central dorsal margin). (p. 408)
23, *24—Loxoconcha?* sp., ×60. *23*, left valve; *24*, dorsal view. (p. 412)
25—Cytherelloidea truncata Schmidt, n. sp. Right valve. (p. 407)
26, *27—Eucythere triordinis* Schmidt, n. sp. *26*, left valve, *27*, right valve. (p. 411)



Schmidt, Cretaceous and Eocene Ostracodes



Schmidt, Cretaceous and Eocene Ostracodes

view. Dorsal and ventral margins straight, subparallel. Anterior margin rounded, compressed; posterior margin compressed, dorsal third concave, ventral two-thirds convex, sloping gently upward to slightly produced caudal process. Posteroventral keel present. No tubercle or eyespot noted. Surface reticulate, reticulations faintly subparallel to margins. Carapace strongly convex. Internal characters unknown.

Dimensions.—Complete specimen, length, 0.50 mm.; height, 0.26 mm.; thickness, 0.23 mm.

Hypotype.—U. S. National Museum 104198, from sample B6.

Occurrence.—Rare in the Aquia formation (B5, 6, C2).

Genus CYTHEROPTERON Sars, 1865
Subgenus CYTHEROPTERON Sars

Genotype: *Cythere latissima* Norman 1865.

Shell ovate in outline. Dorsal margin arched. Ventral margin straight or more or less strongly convex. Anterior end rounded. Posterior end produced to form a short, blunt, narrow, compressed caudal process which curves more or less strongly upward. Carapace widest at ventral margin. Ventro-lateral edges of valves bear more or less strongly developed alaeform lateral expansions. Valves subequal in size, the left valve characteristically slightly larger than the right. Surface smooth or with moderate sculpture.

Hinge of right valve consists of two teeth, one at each end of the hinge line, each bearing several cusps with corresponding notched sockets in the left valve. Hinge margin of left valve, between the terminal sockets, bears a finely crenulate bar, which fits into an obscure, notched furrow between the terminal teeth of the right valve.

Line of concrescence at a moderate distance from, and parallel to, the outer margin of the shell. Inner margin and line of concrescence coincide except at the anterior end, where the course of the inner margin is at a slight distance within that of the line of concrescence. Radial pore canals few, straight, simple.

Muscle-scar pattern consists of a vertical row of four small scars, with either one or two others in front of these.

—Alexander, 1934, p. 229

CYTHEROPTERON (CYPTHEROPTERON) CORYELLI Schmidt, n. sp.
Plate 62, figures 11, 12

Description.—Carapace of right valve subrectangular in side view. In dorsal view resembles triangular arrowhead. Dorsal margin straight. Ventral margin convex, concealed in side view by alate projection. Anterior margin obliquely rounded, forming obtuse angle with dorsal margin; slightly concave at anterior cardinal angle, very slightly produced at ventral angle. Posterior margin narrow, tapering, with dorsally curving caudal process in center. Surface of valves smooth, with faint suggestion of median sulcus. Ventral wings strongly de-

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EXPLANATION OF PLATE 64

Figures ×40 unless otherwise indicated

FIG. *1*—*Paracythereis plusculmenis* Schmidt, n. sp. Left valve. (p. 418)
2–4—*Cythereis plusculmenis* Schmidt, n. sp. *2*, left valve; *3*, right valve; *4*, dorsal view, complete specimen. (p. 422)
5–9—*Cythereis siegristae* Schmidt, n. sp. *5–7*, females; *8*, *9*, males; *5*, *9*, left valves; *7*, *8*, dorsal views; *6*, right valve. (p. 421)
10–12—*Cythereis communis aquia* Schmidt, n. var. *10*, right valve; *11*, left valve; *12*, dorsal view, broken specimen. (p. 420)
13—*Cythereis bassleri* Ulrich. Right valve. (p. 422)
14–15—*Cythereis bassleri reticulolira* Schmidt, n. var. *14*, right valve; *15*, left valve. (p. 423)
16, 17—"*Archicythereis*" *retiplana* Schmidt, n. sp. *16*, left valve; *17*, interior, right-valve, ×60. (p. 417)
18, 19—*Paracythereis potomaca* Schmidt, n. sp. *18*, left valve; *19*, interior, right valve, ×60. (p. 419)
20—*Cythereis pauca* Schmidt, n. sp. Right valve. (p. 420)
21–23—*Clithrocytheridea virginica* Schmidt, n. sp. *21*, left valve, female; *22*, right valve, male; *23*, left valve, male. (p. 429)
24–26—*Clithrocytheridea malkinae* Schmidt, n. sp. *24*, right valve; *25*, left valve; *26*, interior, right valve, ×60. (p. 428)
27, 28—*Clithrocytheridea rugata* Schmidt, n. sp. *27*, left valve; *28*, right valve. (p. 428)
29—*Cytheropteron* (*Cytheropteron*) cf. *midwayensis* Alexander. Left valve. (p. 414)
30, 31—*Clithrocytheridea tombigbeensis* Stephenson. *30*, left valve; *31*, interior, left valve, ×60. (p. 428)

veloped, with compressed outer margins; ventral surfaces bear fine, curved, subparallel striations or ridges, innermost one least distinct. Internal structures characteristic of subgenus.

Dimensions.—Right valve, length, 0.68 mm.; height, 0.38 mm.; thickness, 0.31 mm.

Holotype.—U. S. National Museum 104199.

Occurrence.—Rare in the Monmouth formation at Brightseat, Md.

Remarks.—Muscle scars could not be detected; but all other inner shell characters agreed with the subgenus. This species resembles *C.* (*C.*) *blakei* Alexander 1933, but the alate process is longer and more irregular, a median sulcus is faintly suggested, and the dorsal margin is less evenly arched. Specimens were compared at U. S National Museum with the holotype of *C.* (*C.*) *blakei*. This species is named in honor of Professor H. N. Coryell of Columbia University.

Cytheropteron (Cytheropteron) cf. midwayensis Alexander
Plate 64, figure 29

Cytheropteron (*Cytheropteron*) *midwayensis* Alexander 1934. Jour. Paleontology, vol. 8, no. 2, p. 230, pl. 33, fig. 17.

Dimensions.—Complete specimen, length, 0.68 mm.; height, 0.45 mm.; thickness, 0.41 mm.

Hypotypes.—U. S. National Museum 104200 a, b, from sample E5.

Occurrence.—Rare to abundant in the Aquia formation (E4, 5, G5). Alexander recorded this species from the base of the Wills Point formation (Midway group), Texas.

Remarks.—This form agrees with descriptions of Alexander's species. However, these specimens are longer and higher, but not as wide as his species. Two still longer right valves have been found that may represent the male of this form.

Genus Brachycythere Alexander 1933

Genotype: *Cythere sphenoides* Reuss 1854.

Alexander (1933, p. 204) and Stephenson (1946, p. 331) are followed in their interpretation of this genus. Stephenson's description of internal features is as follows:

"... Hinge structure in right valve consists of a knob-like anterior tooth with postjacent socket, followed by a furrow to the notched posterior tooth. In the left valve, hinge bears an anterior socket with a tooth behind it, to which is attached a bar which extends to the crenulated posterior socket. The bar is below the dorsal margin and separated from it by a depressed furrow. Marginal areas fairly broad, with numerous radial pore canals. Line of concrescence and inner margin coincide throughout. Muscle scar pattern of the genotype, *B. sphenoides* (Reuss), was figured by Alexander (1933, pl. 25, fig. 3c)."

Brachycythere rhomboidalis (Berry)
Plate 62, figures 8–10

Cythere rhomboidalis Berry 1925. Am. Jour. Sci. 5th ser., vol. 9, p. 481, figs. 1, 2.
Cythere rhomboidalis, Alexander 1929. Texas Univ. Bull. 2907, p. 86, pl. VII, figs. 1, 2.
Brachycythere rhomboidalis, Alexander 1933. Jour. Paleontology, vol. 7, no. 2, p. 206.
Brachycythere jerseyensis Jennings 1936. Bull. Am. Paleontology, vol. 23, no. 78, p. 48, pl. 6, figs. 14 a–b.

Description.—Carapace subtriangular in side view, highest at anterior cardinal angle. Valves unequal, left slightly larger than right. Overlap most noticeable dorsally. In dorsal view obovate, widest ventrally about one-fourth length of specimen from posterior. Dorsal margin gently arched. Ventral margin convex, converging posteriorly toward dorsal margin. Anterior margin broadly rounded, more produced ventrally, finely denticulate, and rimmed on well-preserved specimens. Posterior margin narrower, concave dorsally, convex ventrally, and on well-preserved specimens bears about four long spines. Most specimens have blunt bases of spines preserved. Posterior rim present on well-preserved specimens. Anterior and posterior ends compressed. Small depression present on many specimens below anterior cardinal angle. Widest portion of shell is the ventral expansion, which bears a flattened ventro-lateral ridge, separated dorsally from rest of shell by a parallel furrow. Surface pitted, pitting most prominent in center. Alate expansion has two curved subparallel striations or ridges on ventral side, outermost forms ventro-lateral ridge. Internal features typical of genus.

Dimensions.—Complete valve, length, 0.88 mm.; height, 0.49 mm.; thickness, 0.48 mm.; right valve, length, 0.79 mm.; height, 0.45 mm; molt, length, 0.66 mm.; height, 0.40 mm.

Topotype.—U. S. National Museum 104201 a from Brightseat, Md.; hypotypes: (right valve and molt) U. S. National Museum 104201 b, c, from sample E 3.

Occurrence.—Common in the Monmouth formation at Brightseat and at Friendly (E3); rare at Addison Road (D1).

Jennings recorded this species from the Navesink formation of New Jersey and Alexander noted it from the Navarro group of Texas.

Remarks.—Both adults and molts were found. The specimen was incorrectly oriented by Berry. The holotype of *B. jerseyensis* Jennings is similar in all respects.

BRACHYCYTHERE ALATA ATLANTICA Schmidt, n. var.
Plate 61, figures 23, 24

These specimens were compared with plesiotypes of *Brachycythere alata* (Bosquet) Alexander at the U. S. National Museum. Differences in the left valves (the types) are small but constant, as follows: Dorsal margin slightly more arched, posterior dorsal angle or corner convex in *B. alata*, somewhat concave in this variety. Posterior spines more prominent on this variety, although they may have been worn or broken from the others described. No additional spine was noted on the posterior part of the alate process.

Dimensions.—Left valve, length including spines, 0.36 mm.; height, 0.20 mm.; thickness, 0.20 mm. Right valve, length, including spines, 0.36 mm.; height, 0.18 mm.; thickness, 0.20 mm.

Cotypes.—U. S. National Museum 104202 a, b, from sample A2.

Occurrence.—Rare in the Marshalltown formation (A1), in the Mount Laurel sand (A2).

BRACHYCYTHERE ARACHOIDES (Berry)
Plate 62, figures 13–16

Cythere arachoides BERRY 1925. Am. Jour. Sci. 5th ser., vol. 9, p. 484, fig. 5.
Cythere rectangulapora BERRY 1925. Am. Jour. Sci. 5th ser., vol. 9, p. 483, fig. 4.

Description.—Carapace in side view subrhomboidal to pyriform in female, quadrate or rhomboidal in male. Thickest posteriorly and ventrally. Dorsal margin arched, irregular anteriorly where transverse furrow forms notch behind anterior cardinal angle. Angular anterior cardinal angle more noticeable in some females. Anterior margin broadly rounded, curving continuously to the convex ventral margin. Ventral margin slopes upward posteriorly, continuous with convex lower part of posterior margin. Produced caudal process separates the lower part of posterior margin from concave upper part. Anterior and posterior margins compressed, denticulate or spinose. Posterior end usually smooth. Anterior end in well-preserved specimens has two concentric rows of irregular depressions, separated by ridges, forming coarse reticulation pattern, bounded by an irregular subparallel furrow or groove which is quite deep just in front of anterior cardinal angle but dies out ventrally; this changes somewhat in different specimens. A second short, deep groove extends a short distance from dorsal margin just behind anterior cardinal angle. A marked elongate depression lies just posterior and ventral to this groove. A shallow longitudinal groove occurs at center of carapace. Surface coarsely reticulate, depressions between flat ridges roughly parallel to margins. Hinge, muscle scars, radial pore-canals and marginal areas typical of genus.

Dimensions.—Topotypes, male, left valve, length, 0.93 mm.; height, 0.50 mm.; thickness, 0.28 mm.; female, left valve, length, 0.79 mm.; height, 0.46 mm.; thickness, 0.28 mm.; female, right valve, length, 0.79 mm.; height, 0.46 mm.; thickness, 0.23 mm.; molt, right valve, length, 0.70 mm.; height, 0.40 mm.

Topotypes.—U. S. National Museum 104203 a, b, female; c, male; 104204, molt.

Occurrence.—Common in Monmouth formation at Brightseat, and abundant at Addison Road (D1) and Friendly (E2, 3). Molts occur at same localities.

Remarks.—These specimens agree with Berry's illustration of *Cythere arachoides*, probably a female carapace. Molts were found associated with adults but they are much less abundant. The shell is more delicate and the hinge less developed, being a simple crenulate bar and depressions or raised areas. These molts agree with the dimensions and descriptions given by Berry for *Cythere rectangulapora*, which is therefore placed in synonymy.

BRACHYCYTHERE MARYLANDICA (Ulrich)
Plate 63, figures 17–20

Cythere marylandica ULRICH 1901. Maryland Geol. Survey, Eocene vol., p. 119, pl. 16, figs. 16–18.
Brachycythere nanafaliana HOWE and PYEATT 1934, in Howe and Garrett, Louisiana Dept. Cons. Bull. 4, p. 48, pl. 3, fig. 18, pl. 4, figs. 1, 3.
Brachycythere betzi JENNINGS 1936. Bull. Am. Paleontology, vol. 23, no. 78, p. 47, pl. 6, fig. 12 a–c.
Brachycythere nanafaliana HOWE and PYEATT. Murray and Hussey, 1942, Jour. Paleontology, vol. 16, p. 180, pl. 28, figs. 11, 12, tf. 2, fig. 2.
NON *Brachycythere marylandrica* [*sic*] (ULRICH). Murray and Hussey 1942, Jour. Paleontology, vol. 16, p. 174, pl. 27, figs. 7, 8, tf. 2, figs. 11–13.

Description.—Carapace elongate-ovate in side view; quite tumid, thickest toward postero-ventral region. Left valve larger than, and overlaps right. Dorsal margin very gently arched; ventral margin sinuously convex; tumid portion of shell projects over ventral margin posteriorly. Anterior margin denticulate, rimmed, broadly rounded, more oblique dorsally. A slight notch may be present at anterior cardinal angle, more noticeable in male than female specimens. Posterior margin rimmed, narrower, slightly concave dorsally, convex ventrally, with 3 or 4 blunt spines on ventral part. Anterior and posterior margins compressed. Glassy tubercle or eyespot present at anterior cardinal angle, separated posteriorly from tumid part of shell by short deep narrow furrow. Anterior and posterior ends minutely punctate though may appear smooth in some specimens. Tumid portion of valves covered with smooth-topped reticulations with central pits marking position of normal pore-canals. Reticulations become more prominent and coarser ventrally, tend to be subparallel to ventral margin. Four subparallel ridges converging anteriorly are present on broad, flat ventral surface. Outermost ridge forms a ventrolateral keel, visible from side, in many specimens projecting posteriorly as spines. Hingement and internal features characteristic of genus.

Dimensions.—Right valves, male, length, 1.18 mm.; height, 0.61 mm.; female, length, 0.99 mm.; height, 0.58 mm.; complete specimen, female, thickness 0.58 mm.

Hypotypes.—U. S. National Museum 104205 a–d, from sample G 5.

Occurrence.—Abundant in the Aquia formation (B4, 5, 6, 7?, C2, 3, E5, F3, 5, G1, 2, 3, 5, 6, 7, 11, 14). Ulrich recorded this species from the Aquia of Upper Marlboro and Brooks Estate, Md. Howe and Garrett listed it as common in the Nanafalia of Alabama, and rare in the Hatchetigbee of Alabama, and the Sabine at Fort Jessup, La. Jennings noted this species in the Hornerstown of New Jersey. Murray and Hussey reported it from the Wilcox of Louisiana and the Nanafalia and Hatchetigbee of Alabama.

Remarks.—This species, very characteristic of the Aquia formation, is abundant in almost every sample. Two similar ornamented forms usually occur, the shorter, thicker, more ovate form being the female, and the longer, more rhomboid form the male. Female specimens agree with the holotypes of *Cythere marylandica* Ulrich and *B. betzi* Jennings. The male specimens agree in every particular with the descriptions, measurements, and illustrations of *B. nanafaliana* Howe and Pyeatt. The anterior and posterior ends in mature specimens, under high magnification, are seen to be minutely punctate, though free of reticulations. Howe and Pyeatt, and Hussey noted that the ends were smooth in their specimens, but this appears to be a matter of preservation.

Molts differ from the adults mainly in the poorly developed hinge lines. Traces of adult ornamentation are easily discernible. A fairly complete ontogenetic series might easily be worked out for both males and females.

Murray and Hussey (1942) referred *Cythere marylandica* Ulrich 1901 (this name was misspelled) to *Brachycythere* and considered *B. interrasilis* Alexander 1934 to be a synonym. Neither Murray and Hussey's nor Alexander's type specimens have been seen, but they do not mention or figure the ridges on the broad flat ventral surface characteristic of *B. marylandica*. No mention was made of a flat ventral surface by Murray and Hussey, but Alexander wrote " . . . ventral surface broad and flat" for *B. interrasilis*. Murray and Hussey also described *B. nanafaliana* and noted the ventral ridges but apparently recognized no similarity between *B. nanafaliana* and *B. interrasilis*. They had material from the Aquia formation available for study (1942, p. 169,

locality not stated, inferred to be Maryland from chart, p. 168) but they did not identify *B. marylandica* from that material, although they put the Maryland species in synonymy. They did list *B. plena* from the Aquia, a species not found in the present study. It is probable therefore, that they misidentified *B. marylandica*, and that *B. interrasilis* is a distinct species.

"ARCHICYTHEREIS" Howe, 1936

This name, recognized as a synonym of *Cythereis*, is used in quotation to designate molts believed to be referable to that genus but not certainly identified with any described species (see discussion p. 402).

"ARCHICYTHEREIS" RETIPLANA
Schmidt, n. sp.
Plate 64, figures 16, 17

Description.—Carapace subpyriform to subquadrate in side view, thickest posteriorly and ventrally. Dorsal margin straight. Ventral margin straight to faintly convex, slightly sinuous in center. Anterior margin broadly rounded, denticulate. Posterior margin narrow, compressed, subtriangular, slightly concave dorsally, convex ventrally; spines on convex part. Eyespot and subcentral node present; depression behind and below subcentral node. Surface covered with reticulations formed by flat-topped ridges and depressions; pattern follows outline of shell. Faint ridge present on ventral side, starting just behind center and terminated by posterior compression; sometimes ends in projection or subspine. A second similar faint ridge present dorsally and posteriorly. Slightly raised node present posterior to subcentral node and between dorsal and ventral ridges. Hinge in left valve consists of elongate sockets at posterior and anterior cardinal angles, formed mostly by arching of dorsal margin, and connected by thin bar above which may be a groove. In right valve there are elongated, possibly denticulated cusps at posterior and anterior cardinal angles, connected by faint groove. Radial pore-canals at anterior margin. Muscle scars not observed.

Dimensions.—Left valve, length, 0.63 mm.; height, 0.36 mm.; thickness, 0.18 mm.; right valve, length, 0.69 mm.; height, 0.36 mm.; thickness, 0.16 mm.

Cotypes.—U. S. National Museum 104206, from sample B4.

Occurrence.—Rare in the Aquia formation (B4, E5, G5).

Remarks.—This species is very similar to *Cythereis deusseni* Howe and Chambers but differs in that no spines other than those at anterior and posterior margins are present. Howe and Chambers did not mention ridges but from the illustration they might be present. This species also closely resembles *C. russelli* Howe and Garrett as described by Stephenson (1946, p. 339) but differs in presence of a subcentral node, posterior depression, and marked ridges. No adult *Cythereis* present in the material examined is similar enough to imply any ontogenetic relationship.

"ARCHICYTHEREIS" cf. CYTHEREIS PIDGEONI (Berry)
Plate 62, figure 1

Description.—Carapace subpyriform in side view. Highest anteriorly, widest just behind center. Dorsal and ventral margins straight, converging posteriorly. Anterior margin very broadly rounded, slightly rimmed. Posterior margin subtriangular, dorsal third obscurely angulated and produced, ventral two-thirds straight, slanted ventrally. Anterior and posterior margins faintly denticulate. Surface smooth except for four prominent ridges, subcentral node and central depression partly obscured by ridge. A curved high thin ridge parallels ventral margin in central part. Second ridge starts at widest part of shell, goes straight to anterior margin, which it parallels; then just in front of anterior cardinal angle forms third ridge by curving downward and continuing posteriorly, crossing subcentral node and slight posterior depression to die out at widest part. A fourth straight ridge parallels central dorsal margin. All ridges are pierced by subcircular openings but are not prominently buttressed, as in *Cythereis pidgeoni* (Berry). Hinge in right valve consists of straight, simple, faintly crenulate bar. No left valve found.

Dimensions.—Right valve, length, 0.68 mm.; height, 0.33 mm.; thickness, 0.16 mm.

Holotype.—U. S. National Museum 104-207.

Occurrence.—Rare in the Monmouth formation (E3).

Remarks.—The dentition and shape of this specimen suggest that it is a molt, possibly of *Cythereis pidgeoni*, but no other instars have been found to corroborate this. It differs from the latter in the lack of buttresses, in the connection of median ridge with anterior margin, as well as in outline, hingement, and the delicate nature of the shell.

Genus PARACYTHEREIS Jennings, 1936

Genotype: *Paracythereis typicalis* Jennings 1936

Carapace small, subquadrate, inequivalved. Left valve larger than the right; dorsal and ventral margins straight; anterior margin broadly rounded and spinose; posterior margin narrowly rounded and often truncate on the dorsal half; posterior end usually strongly compressed.

Surface of the valves ornamented with pits or reticulations, and ridges. Subcentral tubercle generally present.

Hingement in the right valve consists of a linear crenulate tooth at the anterior dorsal contact, a fine crenulate groove extends along the margin from the anterior tooth to the posterior dorsal contact; a large crenulate tooth is developed on the posterior margin at the posterior dorsal contact. The anterior margin carries a groove, the inner margin of which developes on the ventral margin into a thin ridge over which the left valve fits.

The hingement of the left valve consists of anterior and posterior sockets connected by a finely crenulate bar. A small ridge on the anterior margin fits the groove in the anterior of the right valve; the central portion of the ventral margin of the left valve laps over the ridge of the ventral portion of the right valve forming an internal overlap.

These forms have an outline resembling *Cythereis* but the difference in hingement sets them apart.

—Jennings, 1936, p. 55

Specimens referred to this genus might possibly be molts of *Cythereis* (see p. 403).

PARACYTHEREIS SEMILENIS
Schmidt, n. sp.
Plate 61, figure 14

Description.—Carapace subquadrate in side view, thickest posteriorly and ventrally. Dorsal margin straight, ventral margin sinuous to straight, converging posteriorly. Anterior margin broadly rounded, rimmed; may have few scarcely discernible blunt spines. Posterior margin compressed, concave dorsally, convex ventrally, about four blunt spines on convex part. Eyespot and subcentral node present. Surface seemingly smooth, but when wet shows faint reticulation pattern. A rounded ridge rises behind anterior ventral angle, parallels ventral margin and ends abruptly at posterior compressed area, almost forming a spine or projection above it. Another ridge is present along dorsal margin, roughly paralleling ventral ridge. Hinge characteristic of genus. Radial pore canals present on anterior and posterior margins. Inner margin narrow. Muscle-scar pattern not seen.

Dimensions.—Left valve, length, 0.66 mm.; height, 0.34 mm.; thickness, 0.16 mm.

Holotype.—U. S. National Museum 104-208.

Occurrence.—Rare in the Mount Laurel sand (A2).

Remarks.—These specimens are apparently molts, but they cannot be identified with any associated species of *Cythereis*. At the Addison Road locality (D1) other specimens which differ only in that the ornamentation in general is more emphasized, may be later molt stages but this connection is uncertain.

PARACYTHEREIS PLUSCULMENIS
Schmidt, n. sp.
Plate 64, figure 1

Description.—Carapace subquadrate in side view. Dorsal margin straight, ventral margin somewhat sinuous, bulging slightly in center; margins converge slightly posteriorly. Anterior margin broadly rounded, denticulate. Posterior margin denticulate, compressed, concave dorsally, convex ventrally. Eyespot and subcentral node present. Anterior margin bordered by high, delicate rim, which continues around ventral margin, ending posteriorly in long obliquely projecting spine. Rim less prominent along posterior margin. Surface coarsely reticulated, some reticulations coalescing to form ridges. Prominent thin ridge starts at anterior ventral angle, extends backward for three-fourths the length of carapace, forming high point, then abruptly angles to posterior dorsal region, where it bifurcates; one branch continues to posterior cardinal angle, the other extends anteriorly along dorsal margin, dying out midway between eyespot and subcentral node. A longitudinal

ridge extends posteriorly from subcentral node to transverse posterior ridge. Two other less prominent ridges extend forward from node to anterior rim. Internal features are those of genus.

Dimensions.—Left valve, length, 0.60 mm.; height, 0.31 mm.; thickness 0.15 mm.

Holotype.—U. S. National Museum 104-209, from sample B4.

Occurrence.—Rare in the Aquia formation (B4, 5).

Remarks.—This species may be a molt of *Cythereis plusculmenis*, which occurs abundantly at the same locality. For this reason, the same specific name has been used (see p. 403).

PARACYTHEREIS POTOMACA
Schmidt, n. sp.
Plate 64, figures 18, 19

Description.—Carapace subquadrate to oblong in side view. Dorsal and ventral margins straight, subparallel, converging posteriorly. Anterior margin broad, denticulate. Posterior margin narrower, compressed, concave dorsally, convex ventrally, with some blunt spines. Eyespot and subcentral node present. Surface covered with reticulations. Ridge starts at anterior ventral angle, extends backward to high point above posterior depressed area, turns sharply to posterior cardinal angle, turns anteriorly and extends dorsally to just below eyespot, where it dies out. There is a faint indication of additional ridge connecting subcentral node with transverse posterior ridge. Internal characters those of genus.

Dimensions.—Left valve, length, 0.58 mm.; height, 0.32 mm.; thickness, 0.16 mm.; right valve, length, 0.59 mm.; height, 0.31 mm.; thickness, 0.15 mm.

Cotypes.—U. S. National Museum 104-210 a, b, from sample B4.

Occurrence.—Common in the Aquia formation (B4, 5, 6, G6).

Remarks.—This species appears to be a molt of either *Cythereis bassleri* or *C. bassleri reticulolira* but the slightly emphasized ridges in the posterior cardinal corner favors the latter.

Genus CYTHEREIS Jones, 1849

Genotype: *Cytherina ciliata* Reuss 1846= *Cythereis ornatissima* (Reuss) 1846.

Carapace subquadrate, highest anteriorly. Dorsal and ventral margins usually straight or weakly convex, normally converging posteriorly. Anterior end rounded, posterior end subangular, often denticulate on their ventral portions. Ornamentation exceedingly variable, including spines, pits or ridges, at times in various complex combinations. A subcentral inflated node anterior to middle of carapace, present on many species, is a feature stressed by earlier workers. Eyespot usually visible below anterodorsal angle, often prominent. Hinge structure normally well developed, in the right valve with strong teeth at the cardinal angles. A rounded socket postjacent to anterior tooth joins a groove which extends to posterior dentition. In the left valve, terminal sockets articulate with the teeth of the opposite valve. A knob-like swelling or tooth behind the anterior socket is attached to the dorsal margin, which margin continues as a bar to the posterior socket. Alexander (1933, p. 209) pointed out that the hinge of *Cythereis* differs from that of *Brachycythere* in that this bar is the dorsal edge of the valve, and is not below and distinct from it as in *Brachycythere*. Muscle-scar pattern is usually obscured by surface ornamentation.

—Stephenson, 1946, p. 334

CYTHEREIS COMMUNIS Israelsky
Plate 61, figures 11–13

Cythereis communis ISRAELSKY 1929. Arkansas Geol. Survey Bull. 2, p. 14, pl. 3a, figs. 9–13.
Cythereis communis, ALEXANDER 1929. Texas Univ. Bull. 2907, p. 101, pl. 9, fig. 18.
Cythereis communis, JENNINGS 1936. Bull. Am. Paleontology, vol. 23, no. 78, p. 52, pl. 7, fig. 3.

Description.—Carapace oblong to subquadrate in side view. Thickest ventrally and posteriorly. Dorsal margin straight, partly concealed by irregular bulbous dorsal ridge. Ventral margin straight, converges posteriorly with dorsal margin. Anterior broadly rounded, thick, rimmed, with eight or more blunt spines on ventral part. Slight notch between dorsal and anterior margins. Posterior margin strongly compressed, angular, dorsal part concave, ventral bluntly convex, with about four long blunt spines. Prominent eyespot present at anterior cardinal angle. Anterior margin has broad thick rim, starting at eyespot, turns at anterior ventral angle and forms thick, almost bulbous ridge extending longitudinally parallel to ventral margin and out from surface of shell. It is terminated abruptly by compressed posterior region. An irregular dorsal ridge starts at anterior cardinal angle, and a median longitudinal bulbous ridge rises behind anterior marginal depression; both extend to and are terminated by posterior compressed area. The median ridge is less well defined and is bulbous in anterior third. The dorsal ridge ends posteriorly in

well rounded expansion, and turns very slightly downward. Surface sparsely punctate. Hingement characteristic of genus. Muscle scars not seen. Radial pore-canals about three or more to a spine anteriorly and posteriorly.

Dimensions.—Left valve, length, 0.75 mm.; height, 0.41 mm.; thickness, 0.20 mm.; right valve, length, 0.75 mm.; height, 0.40 mm.; thickness, 0.23 mm.

Hypotypes.—U. S. National Museum 104211 a–c, from sample A1.

Occurrence.—Abundant in the Marshalltown (A1) and Mount Laurel (A2) formations. Israelsky recorded this species from the Ozan, Annona, Marlbrook, Saratoga, Nacatoch, and Arkadelphia formations (*Exogyra ponderosa* and *Exogyra costata* zones) of Arkansas. Alexander listed it from the Navarro of Texas. Jennings reported it from the Mount Laurel and Navesink of New Jersey.

Remarks.—Specimens from the Marshalltown formation, like those illustrated, have no connection between the dorsal and median ridges, but in Mount Laurel specimens a faint connecting ridge joins the posterior ends. A longer left valve (length, 0.78 mm.; height, 0.41 mm.) which might be a dimorphic variety, is illustrated in figure 11. Israelsky's holotype and paratypes are identical with these specimens.

A new species referred to *Cythereis* (*Pterygocythereis*) in a manuscript by F. M. Swain on the ostracodes from the Ohio No. 1 Hammond well is stated to be nearly identical with *C. communis*. Comparison of holotypes has proved them to be identical.

Cythereis communis aquia Schmidt, n. var.
Plate 64, figures 10–12

These specimens differ from *C. communis* as follows: Shell smaller; ventral ridge less alate and less prominent; dorsal ridge noded rather than bulbous; all specimens have faint raised connection between median and dorsal ridges; anterior spines less prominent; more surface punctations.

Dimensions.—Left valve, length, 0.61 mm.; height, 0.32 mm.; right valve, length, 0.60 mm.; height, 0.31 mm.; complete specimen (paratype) thickness, 0.32 mm.

Cotypes and paratype.—U. S. National Museum 104212 a–c.

Occurrence.—Rare in the Aquia formation (G11).

Remarks.—This may be an Eocene derivative of *C. communis*. The connection between median and dorsal ridges, which appears on a few Mount Laurel specimens, is characteristic of all these specimens.

Cythereis pauca Schmidt, n. sp.
Plate 64, figure 20

Description.—Carapace subquadrate in side view. Dorsal and ventral margin straight, converge posteriorly. Anterior margin rimmed, denticulate. Posterior margin rimmed, subtriangular, compressed; three or four spines present ventrally. Three subdued, rounded, longitudinal ridges present, terminated by posterior compressed area. Ventral ridge is continuation of anterior rim, and forms high point of shell at posterior termination. Median ridge starts at elongated subcentral node, extends posteriorly, then slopes upward to join dorsal ridge near posterior cardinal angle. Coarse reticulation pattern covers entire shell, not always noticeable on ridges. Hinge characteristic of genus.

Dimensions.—Right valve only, length, 0.73 mm.; height, 0.36 mm.; thickness, 0.15 mm.

Holotype.—U. S. National Museum 104213.

Occurrence.—Rare in the Aquia formation (B4).

Remarks.—This species is larger than *C. communis aquia*, but about the same size as *C. communis*. It differs from *C. communis aquia* as follows: Ridges more subdued; dorsal and median ridges joined by definite slanting connection; spines on anterior and posterior margins more prominent; posterior area gradually compressed: surface coarsely punctate to slightly reticulate along dorsal and anterior margins. The specimens look as though they had been worn.

Cythereis costatana angula Schmidt, n. var.
Plate 61, figures 17, 18

Description.—Carapace quadrate in side view. Dorsal and ventral margins straight with only slight posterior convergence; dorsal margin may be slightly irregular. Anterior margin very broadly rounded, denticulate, rimmed. Posterior margin nar-

rower, subtriangular, compressed, thickly rimmed and denticulate. Projecting spine commonly preserved at posterior ventral border. Glassy eyespot present, subcentral node barely discernible. Rounded, almost bulbous, ridge extends backward from antero-ventral region to posterior compressed area. A similar dorsal ridge starts below eyespot, extends backward, making almost right-angled turn and ending above posterior compressed area. Entire surface finely punctate or reticulate. In depression behind rimmed anterior margin are about two subparallel rows of elongate reticulations; one row continues less distinctly posteriorly beneath dorsal ridge. Hinge and other internal features characteristic of genus.

Dimensions.—Complete specimen, length, 0.75 mm.; height, 0.38 mm.; thickness, 0.23 mm.

Holotype.—U. S. National Museum 104-214, from sample A1.

Occurrence.—Abundant in the Marshalltown formation (A1); common in the Mount Laurel sand (A2).

Remarks.—These specimens differ from the holotype of *C. costatana* Israelsky in having their posterior compressed parts longer and their posterior cardinal angles more nearly at right angles. They are very similar to *C. pulchra* Jennings 1936 except that the ridges are more prominent, and the reticulations or pits fewer in these specimens. The dorsal part of posterior margin is almost straight in *C. pulchra;* it is concave in this variety.

CYTHEREIS PIDGEONI (Berry)
Plate 62, figures 2–6

Cytheridea pidgeoni BERRY 1925. Am. Jour. Sci., 5th ser., no. 9, p. 485, figs. 7, 8.

Description.—Carapace subquadrate to oblong in side view, highest anteriorly. Dorsal and ventral margins straight, converging posteriorly. Slight sinuosity in anterior third of ventral margin where ventral edge of left valve slightly overlaps right valve. Dorsal and ventral margins subparallel in male. Anterior margin broadly rounded, spinose or denticulate, rimmed, somewhat more produced ventrally in female. Posterior margin subtriangular with dorsal third obscurely angulated, slightly produced; ventral two-thirds straight. A high, thin ridge borders ventral edge from antero-ventral to postero-ventral angle. Four or five separated large, blunt spines present on posterior margin. A prominent high thin ridge starts at posterior cardinal angle, follows margin around anterior to anterior ventral angle, then extends straight back along lowest third of shell to flattened posterior triangle. A similar median ridge starts at posterior with slight ventral curve and just past center bifurcates and dies out. These ridges are buttressed by smaller ridges, and on many shells small windows in ridges are present close to surface of shell giving a fenestrated appearance. These ridges may be worn down and broken in some shells (see fig. 6). The anterior and posterior parts of shell are free of ornamentation, and surface is otherwise smooth. Where preserved, the anterior inner margin is quite broad. Hinge characteristic of genus.

Dimensions.—Complete specimen, male, left valve, length, 0.83 mm.; height, 0.43 mm.; right valve, length, 0.85 mm.; height 0.45 mm.; female, left valve, length, 0.70 mm.; height, 0.42 mm.; right valve, length, 0.71 mm.; height, 0.38 mm.; thickness complete specimen, female, 0.38 mm.

Chorotypes.—U. S. National Museum 104215 a–e, from sample E3.

Occurrence.—Common to abundant in the Monmouth formation (D1, Brightseat, E2, 3).

Remarks.—This species is very characteristic of the Monmouth. It has been found at all localities, and in no other formation. Specimens from sample E3 are figured because they are better preserved than those from Brightseat, and both male and female carapaces are present. "*Archicythereis*" cf. *C. pidgeoni* from the Monmouth formation is probably a molt of this species.

The arrangement of ridges on this species is very similar to that of *C. huntensis* (Alexander) although the ridges themselves are quite different. This may be a more highly evolved species of the same group.

CYTHEREIS SIEGRISTAE Schmidt, n. sp.
Plate 64, figures 5–9

Description.—Carapace subquadrate to oblong in side view, highest anteriorly. Dorsal and ventral margins straight, converging posteriorly. Anterior margin broadly

rounded, rimmed, denticulate or spinose. Posterior margin triangular, spinose, slopes anteriorly to ventral margin, produced in central part. Prominent eyespot present at anterior cardinal angle. Subcentral curved depression present. Double row of spines on anterior and posterior margins; anterior spines blunt, posterior spines more prominent on ventral slope. Two ridges start just in back of depression behind anterior rimmed margin; dorsal ridge crosses subcentral node; ventral ridge closely parallels ventral margin; both die out in posterior third of shell. Surface very coarsely reticulate, pattern roughly following outline of shell. Reticulations sharply crested in many individuals, but not spiny. Hinge characteristic of genus. Radial pore-canals about 13 in anterior margin, about one for each spine. About 15 radial pore-canals in posterior. Inner margin present, broad at anterior.

Dimensions.—Male, left valve, length, 0.75 mm.; height, 0.40 mm.; thickness (complete specimen) 0.30 mm.; female, left valve, length, 0.76 mm.; height, 0.45 mm.; right valve, length, 0.71 mm.; height, 0.40 mm.; thickness (complete specimen) 0.37 mm.

Holotype.—U. S. National Museum 104-216a, paratypes 104216 b–e, from sample E5.

Occurrence.—Rare to very abundant in the Aquia formation (B4, 5, 6, C3, E5, F5, G3, 5).

Remarks.—The male is longer with more parallel margins than the female. This species closely resembles the figure of *C. orelliana* (Stadnichenko) but all descriptions of the latter note the presence of spines over whole surface. The holotype of *C. orelliana* is not reticulate but has node-like ridges quite unlike the crested but not spiny ridges of this species. Swain has described a similar species in manuscript, but its ridges are less pronounced, its postero-ventral angle is more gently curved, and its surface is somewhat more spiny. This species is named in honor of Marie Siegrist, of the Foreign Bibliography of the Geological Society of America.

CYTHEREIS PLUSCULMENIS Schmidt, n. sp.
Plate 64, figures 2–4

Description.—Carapace oblong-subquadrate in side view. Dorsal and ventral margins straight, subparallel, converge slightly posteriorly. Ventral margin very slightly sinuous anteriorly. Anterior margin broadly rounded, denticulate, with thickened rim. Posterior margin compressed, concave dorsally, convex ventrally with blunt spines. Prominent glassy eyespot at anterior cardinal angle; subcentral node present. Anterior margin bordered by high rim, which continues around ventral and posterior margins less prominently. Surface covered by network of very coarse reticulations, which coalesce, forming about four prominent ridges; in some specimens only ridges are present. Prominent ridge starts at anterior ventral angle, extends backward to one-fourth the length of carapace from posterior, forms high point, there abruptly turns toward posterior cardinal angle, where it continues forward along dorsal margin to just below eyespot, and there turns ventrally to subcentral node. This much of the ornamentation is somewhat similar to *C. collei* Gooch. A second longitudinal ridge extends posteriorly from subcentral node to transverse ridge; two others, less prominent in some specimens, are parallel and extend anteriorly from subcentral node to depression behind anterior rim. Hinge characteristic of genus. Radial pore-canals present at anterior and posterior margins.

Muscle-scar pattern not observed.

Dimensions.—Left valve, length, 0.69 mm.; height, 0.35 mm.; right valve, length, 0.71 mm.; height, 0.38 mm.; thickness, complete specimen, 0.37 mm.

Holotype.—U. S. National Museum 104-217 a, paratypes, 104217 b, c, from sample B4.

Occurrence.—Very abundant to rare in the Aquia formation (B4, 5, 6, C3).

Remarks.—This species closely resembles *C. collei* Gooch but is more ornate. *Paracythereis plusculmenis* n. sp. is very likely a late molt of this species.

CYTHEREIS BASSLERI Ulrich
Plate 64, figure 13

Cythereis bassleri ULRICH 1901. Maryland Geol. Survey, Eocene vol., p. 120, pl. 16, figs. 19–21.

Dimensions.—Right valve only, length, 0.58 mm.; height, 0.30 mm.; thickness, 0.18 mm.

Hypotype.—U. S. National Museum 104-218, from sample E5.

Occurrence.—Rare in the Aquia formation (E5). Ulrich described this species from Upper Marlboro, Md.

Remarks.—This specimen agrees both with Ulrich's figured specimen and the holotype. The "less prominent ridge (that) runs from the high end of the ventral ridge in a slightly oblique direction to posterior cardinal angle and then turns forward" (Ulrich 1901, p. 120) is characteristic. The coalescing ridges form a single, low ridge, connecting the posterior ridge with the subcentral node. This specimen has a slightly more concave dorsal posterior margin than the holotype. Different preservation makes its ridges appear more prominent. As some other specimens in the U. S. National Museum identified as *C. bassleri* differ from the holotype, the occurrence of this specimen and the type only are given.

CYTHEREIS BASSLERI RETICULOLIRA Schmidt, n. var.
Plate 64, figures 14, 15

Description.—Carapace oblong-subquadrate in side view. Dorsal and ventral margins straight, subparallel, converging slightly toward posterior. Anterior margin broadly rounded, denticulate, rimmed. Posterior margin compressed, concave dorsally, convex ventrally with several (four to six or more) blunt spines which may be almost worn away. Margin thick. Glassy eyespot at anterior cardinal angle. Anterior margin has high rim, margined by inner depression. Rim present on all other margins, but less prominent. High subcentral node present. Entire surface coarsely reticulate. Prominent ridge starts at anterior ventral angle, extends backward to point about one-fourth the length of carapace from posterior where it forms a high point, bends and continues irregularly dorsally, meeting second ridge. Second ridge more obviously a coalescing of reticulations, starts beneath eyespot, follows dorsal margin to posterior cardinal angle, bends obliquely forward through an angle of 90 or less degrees and extends as a wide-mouthed U to the subcentral node. The ventral ridge meets this one irregularly at the base of U. In some specimens reticulations become more prominent behind and above the subcentral node, but this seems to be individual variation and may differ on right and left valves of the same individual. Hinge characteristic of genus. Radial pore-canals present in anterior and posterior margins, dying out ventrally. Muscle-scar pattern not observed.

Dimensions.—Left valve, length, 0.68 mm.; height, 0.36 mm.; thickness, 0.18 mm.; right valve, length, 0.66 mm.; height 0.35 mm.; thickness, 0.17 mm.

Holotype.—U. S. National Museum 104-219, from locality B4.

Occurrence.—Rare to very abundant in the Aquia formation (B4, 6, G11).

Remarks.—These specimens differ from *C. bassleri* Ulrich in the following ways: wide U-shaped dorsal and posterior ridge more consistent; anterior more prominently denticulate, although this may depend on preservation; rounded rather than pointed posterior ventral projection. They differ from *C. claibornensis* Gooch, and *C. hysonensis* Howe in the character of their posterior cardinal ridges.

CYTHEREIS BASSLERI VACUITATIS Schmidt, n. var.
Plate 61, figures 19, 20

Description.—Anterior margin denticulate. Surface covered with coarse reticulations. Prominent glassy eyespot and subcentral node. A ridge starting on dorsal margin in front of eyespot parallels anterior margin, and fades out on ventral margin. A second ridge starts at anterior ventral angle, rises gradually to posterior quarter, where it ends abruptly. Another ridge starts just below posterior cardinal angle where it makes a right-angled turn, parallels dorsal margin and dies out before reaching eyespot. Subcentral node is very prominent and covered with reticulations. Outline, margins, and internal features same as in *C. bassleri reticulolira*, n. var.

Dimensions.—Right valve, length, 0.65 mm.; height, 0.38 mm.; thickness, complete specimen, 0.36 mm.

Holotype.—U. S. National Museum 104-220 a, paratype, 104220 b.

Occurrence.—Common in the Marshalltown formation (A1).

Remarks.—These specimens differ from *C. bassleri* in having no posterior connection between their dorsal and ventral ridges.

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Genus HAPLOCYTHERIDEA
Stephenson, 1936

Genotype: *Cytheridea montgomeryensis* Howe and Chambers 1935

HAPLOCYTHERIDEA LEEI
(Howe and Garrett)
Plate 63, figures 8, 9

Cytheridea leei HOWE and GARRETT 1934. Louisiana Dept. Cons. Geol. Bull. 4, p. 33, pl. 1, figs. 22, 23.
Cytheridea (*Haplocytheridea*) *leei*, Stephenson, 1938, Jour. Paleontology, vol. 12, p. 572, pl. 67, figs. 4, 5, tfs. 1, 2.

Dimensions.—Complete specimens, male: length, 0.84 mm.; height 0.48 mm.; thickness, 0.40 mm.; female: length, 0.84 mm.; height, 0.53 mm.; thickness, 0.45 mm.

Hypotypes.—U. S. National Museum 104221 a, b, from sample G14.

Occurrence.—Common to rare in the Aquia formation (B6, 7?, C2, 3, E4, 5, F3, G6, 11, 14). Howe and Garrett recorded this species from the Sabine group at Fort Jessup, La., and from the Nanafalia formation of Alabama. Stephenson likewise noted it from the latter formation.

Remarks.—This species is common in Virginia and Maryland. Both male and female valves were found at most localities, and show the marked sexual dimorphism which was recorded by Stephenson (1938). The hingement and muscle-scar pattern are typical, as is the somewhat variable pitting which readily distinguishes this species.

HAPLOCYTHERIDEA VEATCHI AQUIA
Schmidt, n. var.
Plate 63, figures 1–7

These specimens, which are very abundant, were at first identified as *Haplocytheridea moodyi* (Howe and Garrett) 1934, as illustrated and described by Howe and Garrett, and by Stephenson. Highly arched females and somewhat longer, lower-arched male specimens commonly occur together. The strongly arched dorsal margins of the females, the slight convexity of the ventral margins, and the general lack of ventral curvilinear furrows at both ends agree closely with the descriptions of *H. moodyi*. The longer male specimens might be identified as *H. veatchi* Howe and Garrett. Their ventral margins appear to be similar (see Stephenson, 1938, p. 575) but furrows are not always present anteriorly and posteriorly.

As this paper was nearing completion, the U. S. National Museum received from Stephenson a suite of Weches ostracodes from Texas, including specimens of *H. moodyi* and *H. veatchi*, the representative of the latter probably a female. These specimens show the species to be quite different. *H. moodyi* has the vertical furrows confined to little more than the central third of the shell and has a straighter ventral margin than *H. veatchi*, which is somewhat convex ventrally, as are the specimens under consideration. (Stephenson, description of *H. veatchi*, 1938, p. 574, " . . . ventral margin straight . . . "; 1946, p. 325, " . . . ventral margin somewhat convex . . . .") *H. veatchi* also agrees with the present specimens in the possession of a posterior ventral spine.

H. veatchi aquia differs from *H. veatchi* as follows: The curvilinear vertical furrows generally are absent from the anterior and posterior ends (as in *H. moodyi*) although some specimens show faint indications of them. There are no posterior beaded ridges (Howe and Garrett, 1934, p. 44) or papillae (Stephenson, 1946, p. 325). Female individuals are very similar to Stephenson's specimens of *H. veatchi* in outline; males are longer, and less highly arched dorsally.

The specimen illustrated in figure 1 is a fragile shell, probably a molt. Most similar specimens are found broken. These shells appear minutely punctate and incipient furrows can be seen in some. A median furrow is always present. The hinge is characteristic of *Haplocytheridea*, as is the muscle-scar pattern which is readily seen through the transparent shell. Such molts were found in samples E5, G3, and 5, in all of which mature specimens are common. The illustrated left valve from sample G3 measured: length, 0.60 mm.; height, 0.35 mm.

Dimensions.—Male, left valve, length, 0.84 mm.; height, 0.45 mm.; right valve, length, 0.81 mm.; height, 0.41 mm.; complete specimen, thickness, 0.35 mm. Female, left valve, length, 0.75 mm.; height, 0.45 mm.; right valve, length, 0.73 mm.; height, 0.41 mm.; complete specimen, thickness, 0.36 mm.

Holotype.—U. S. National Museum 104-

222 a, paratypes 104222 b–g, male from sample E5, female from sample G5.

Occurrence.—Abundant in the Aquia formation (B4, 5, 6, E4, 5, F3, 4, 5, G2, 3, 5, 6, 11?).

HAPLOCYTHERIDEA PUNCTURA
Schmidt, n. sp.
Plate 61, figures 27–31

Description.—Carapace small, tumid, subtriangular in outline. Highest at anterior cardinal angle. In females the highest point is almost at the middle; in males it is more anteriorly located. Dorsal margin strongly arched, almost angular in female. Ventral margin gently convex, in right valve slightly sinuate anteriorly. Anterior margin very broadly rounded, denticulate. Posterior margin narrow, blunt, with subacute postero-ventral angle, denticulations barely discernible. Anterior and posterior margins generally transparent. Surface coarsely punctate, each pit marking the position of normal pore canals; otherwise smooth; appears glossy in some specimens. Hinge in left valve consists of terminal notched or crenulated sockets, connected by crenulate bar which is separated from dorsal margin by a groove. In right valve are terminal raised notched cusps or teeth, connected by a crenulate bar beneath which is a crenulate groove. Muscle-scar pattern characteristic of genus. Radial pore-canals numerous, easily seen through transparent margin from exterior; straight, about 25-30 on anterior margin. Inner margin coincides with line of concrescence except at anterior margin.

Dimensions.—Male, left valve, length, 0.53 mm.; height, 0.32 mm.; thickness, 0.16 mm.; right valve, length, 0.51 mm.; height, 0.30 mm.; thickness, 0.12 mm. Female, left valve, length, 0.51 mm.; height, 0.35 mm.; thickness, 0.18 mm.

Holotype.—U. S. National Museum 104-223 a, paratypes 104223 b, c.

Occurrence.—Very abundant in the Marshalltown formation (A1).

Remarks.—Except for the absence of the lowermost crenulate groove in left valve the hinge is similar to that of Cretaceous species of the genus.

This species resembles a form described in manuscript by Swain except for the absence of a posterior dorsal depression and difference in outline.

HAPLOCYTHERIDEA? PLUMMERI
(Alexander)
Plate 62, figures 27–29; text figure 2 f

Cytheridea plummeri ALEXANDER 1929. Texas Univ. Bull. 2907, p. 73, pl. 5, figs. 5–8.
Cytheridea plummeri, ALEXANDER and ALEXANDER, 1933, Am. Midland Naturalist, vol. 14, no. 3, p. 283, figs. 1–4.

Dimensions.—Male, left valve, length, 0.91 mm.; height, 0.50 mm.; thickness (complete specimen) 0.43 mm. Female, left valve, length, 0.75 mm.; height, 0.44 mm.; right valve, length, 0.70 mm.; height, 0.41 mm.

Hypotypes.—U. S. National Museum 104224 a–d. Females from sample D1, males from sample E3.

Occurrence.—Abundant in the Mount Laurel sand (A2); common in the Monmouth formation (D1, E3). Alexander described this species from the Taylor formation of Texas.

Remarks.—These specimens agree with Alexander's description and illustration of *Cytheridea plummeri*. He did not mention, but his illustrations show blunt spines or denticulations on the anterior margin, and on the posterior part of the ventral margin. The plump part in the right valve of many of these specimens overhangs the central part of the ventral margin; this is probably a dimorphic character. Specimens that appear to be molts of this or a closely related species occur without associated adults in samples E2 and E3 and at Brightseat.

This species probably is referable to *Haplocytheridea* (see discussion on page 403). The normal "bar" between the teeth in the right valve seems to be represented by a groove in these specimens, and the crenulated groove below the bar in the left valve is extremely difficult to see.

HAPLOCYTHERIDEA? MACROPORA
(Alexander)
Plate 62, figure 24

Cytheridea macropora ALEXANDER 1929. Texas Univ. Bull. 2907, p. 77, pl. 5. fig. 15.

Dimensions.—Complete specimen, length, 0.60 mm.; height, 0.33 mm.; thickness, 0.26 mm.

Hypotype.—U. S. National Museum 104-225, from sample E3.

Occurrence.—Common to rare in the Monmouth formation (D1, E3, Brightseat). Alexander described this species from the uppermost Navarro of Texas.

Remarks.—These specimens agree with the one figured and described by Alexander. It was noted in addition that the left valve is larger than, and overlaps the right valve, more so dorsally and ventrally. The hinge of this species is identical to that described for other forms assigned questionably to *Haplocytheridea* (see discussion, p. 403).

HAPLOCYTHERIDEA? FABAFORMIS (Berry)
Plate 62, figure 23; text figure 2 e

Cytherella fabaformis BERRY 1925. Am. Jour. Sci. 5th ser., vol. 9, p. 487, fig. 13.
Cytheridea fabaformis, ALEXANDER, 1929, Texas Univ. Bull. 2907, p. 76, pl. 5, fig. 18.
Cytheridea fabaformis, ALEXANDER 1934, Jour. Paleontology, vol. 8, p. 224.

These specimens, which agree with Alexander's description of external features, have the dorsal margin moderately rather than gently arched. In the right valve, the ventral posterior angle is more produced than in the left where it is blunt.

The muscle-scar pattern is typical of *Haplocytheridea*. The hinge in the left valve agrees with that described by Alexander and Alexander (1933), except that no crenulate groove can be detected beneath the bar. It consists of terminal crenulated or notched sockets, a crenulated bar connecting them, and a decided groove between the bar and dorsal margin. Terminal notched raised cusps or teeth connected by a narrow crenulated groove are present in the right valve and the dorsal margin overlaps the groove slightly.

Dimensions.—Left valve, length, 0.65 mm.; height, 0.36 mm.; thickness 0.16 mm.

Hypotype.—U. S. National Museum 104-226, from Sample D1.

Occurrence.—Common in the Monmouth formation (D1, E2, 3, Brightseat). Alexander described this species from the basal clays of Kincaid in the Navarro of Texas.

Remarks.—See discussion of hinge, p. 403.

HAPLOCYTHERIDEA? FABAFORMIS MULTILIRA Schmidt, n. var.
Plate 62, figures 25, 26

This specimen is very similar to *H.? fabaformis* (Berry). The internal characters of the left valve, which overlaps the right, seem to be identical. This variety, however, is somewhat larger than *H.? fabaformis* and several parallel ridges occur on the ventral side, continuing along the anterior and posterior margins.

Dimensions.—Left valve, length, 0.66 mm.; height, 0.40 mm.; complete specimen, thickness, 0.35 mm.

Holotype.—U. S. National Museum 104-227 a, paratype 104227 b.

Occurrence.—Rare in the Monmouth formation (E3).

HAPLOCYTHERIDEA? AMYGDALOIDES BREVIS (Cornuel)
Plate 62, figures 20–22

Cythere amygdaloides var. *brevis* CORNUEL 1846. Mem. Soc. Geol. France, ser. 2, vol. 1, pt. 2, p. 199, pl. 8, fig. 12.
Cytheridea amygdaloides var. *brevis* ALEXANDER, 1929, Texas Univ. Bull. 2907, p. 70, pl. 4, fig. 13.

These specimens agree with Alexander's description. The surface punctations mark the openings of normal pore canals. On the more weathered specimens, the central four to six pits, which are deepest and commonly most conspicuous on other specimens, are usually the only ones immediately noticeable. The muscle-scar pattern, which may be difficult to see, is similar to that described for *Haplocytheridea*. The radial pore-canals are fine, slender, and numerous. The hinge is similar to that described for *H.? fabaformis* (Berry).

Dimensions.—Left valve, length, 0.58 mm.; height, 0.36 mm.; right valve, length, 0.58 mm.; height, 0.32 mm.

Hypotypes.—U. S. National Museum 104228 a–c, from sample E3.

Occurrence.—Common in the Monmouth formation (D1, E3, Brightseat). Alexander reported this variety from the upper part of the Goodland and the Kiamichi of Texas.

HAPLOCYTHERIDEA? ULRICHI (Berry)
Plate 62, figures 18, 19

Cythere ulrichi BERRY 1925. Am. Jour. Sci., 5th ser., vol. 23, no. 9, p. 483, fig. 3.

Description.—Carapace elongate-ovate in side view, highest about middle. Valves widest centrally, or just behind center. Dorsal margin arched. Ventral margin slightly convex, somewhat sinuous anteriorly. An-

terior margin broadly to obliquely rounded, denticulate; in well-preserved specimens it bears a rim or frill of denticulations or spines. Posterior margin narrow, postero-ventral angle subacute, somewhat produced in right valve and may bear spines. Surface smooth, glossy in well-preserved specimens, with large scattered circular pits marking position of normal pore-canals. Muscle-scar pattern typical of *Haplocytheridea:* 6 scars, 4 in vertical row, 2 in front. Inner margin moderately wide (about 0.05 mm. anteriorly), does not coincide with line of concrescence anteriorly. Radial pore-canals numerous, slender, straight, about 30 around anterior margin. Hinge, in right valve, consists of terminal elongate cusps or teeth with transverse ridges, connected by crenulated groove or furrow. In left valve, terminal elongate sockets with transverse ridges or depressions are connected by raised crenulated bar and separated from the dorsal margin by an elongate, deep groove.

Dimensions.—Right valve, length, 0.66 mm.; height, 0.30 mm.

Topotype.—U. S. National Museum 104-229, from Brightseat.

Occurrence.—Rare in the Monmouth formation (E2, 3, Brightseat).

Remarks.—The hinge is like that in other species questionably assigned to *Haplocytheridea* (see discussion p. 403). The left valve was lost before final measurements and photographs could be made.

HAPLOCYTHERIDEA PINOCHII (Jennings)
Plate 61, figures 25, 26

Cytheridea pinochii JENNINGS 1936. Bull. Am. Paleontology, vol. 23, no. 78, p. 58, pl. 7, fig. 9.

Description.—Carapace small, inequivalved, subovate in lateral view; greatest height slightly anterior to the center; dorsal margin arched and obscurely angulated; anterior margin broadly rounded, sparsely and obscurely denticulated; ventral margin slightly convex in the center and slightly sinuous in the posterior third; posterior end narrowly rounded and truncated in the dorsal half; left valve overlaps the right on the entire margin, overlap slightly stronger on the dorsal margin; surface of the valves punctate, the strongest punctations arranged in a row slightly posterior to the center in a pronounced furrow. Length, 0.70 mm.; height, 0.45 mm.; thickness, 0.37 mm.

This form differs from *Cytheridea monmouthensis* in that the posterior end is not as acute as the one Berry describes and the wing on the posterior ventral margin is missing. Forms that resemble this were described by Alexander from the Cretaceous of Texas but they were even more angular at the posterior contact than were the forms illustrated by Berry.

Mt. Laurel. Columbia University Coll. No. M23.

—Jennings, 1936

Dimensions.—Left valve, length, 0.71 mm.; height 0.45 mm.

Hypotype.—U. S. National Museum 104-230.

Occurrence.—Rare in the Mount Laurel formation (A2).

Remarks.—This specimen agrees with Jennings' description, measurements and comments. When compared with the holotype, it was noted that the greatest height is more posterior in these specimens and the dorsal posterior angle is less prominent. Only left valves were found and these differences do not seem important. The hingement in the left valve is that of *Haplocytheridea* but the crenulated groove beneath the narrow bar is missing (see p. 403). There are terminal notched sockets, and a connecting crenulate bar separated from the dorsal margin by a groove.

Genus CLITHROCYTHERIDEA
Stephenson 1936

Genotype: *Cytheridea? garretti* Howe and Chambers 1935.

Viewed from the side, the carapace of members of this genus is elongate, subpyriform to subquadrate. Dorsal margin arched and sloping toward posterior; ventral margin straight to somewhat convex. Anterior end is high, well rounded, at times bluntly denticulate on ventral half. Posterior end lower, sloping to narrowly rounded or subacute postero-ventral angle. Surface of valves smooth, pitted, or variously ornamented, some species showing heavy sculpturing. Hinge structure diagnostic in determination of genus. In the right valve, raised, terminal, taxodont dental areas are notched to form several cusps. These dentitions are truncated into a crenulate groove forming the hinge line between them. In the left valve, elongate, notched, well incised sockets articulate with the dentitions of the right valve, and these sockets are joined by an elevated, crenulated bar. In many species the marginal area of the right valve is equipped with an acute carina, just inside and parallel to outer edge of valve, which fits into a groove or lip line in the left valve.

—Stephenson, 1946, p. 326

CLITHROCYTHERIDEA TOMBIGBEENSIS
Stephenson
Plate 64, figures 30, 31

Clithrocytheridea tombigbeensis STEPHENSON 1938. Jour. Paleontology vol. 12, p. 579, pl. 67, figs. 1, 2, tfs. 30, 31.

Dimensions.—Left valve, length, 0.71 mm.; height, 0.43 mm.

Hypotype.—U. S. National Museum 104-231, from sample G11.

Occurrence.—Rare in the Aquia formation (G11, 14). Stephenson reported this to be common in the Hatchetigbee and Bashi of Alabama.

Remarks.—These distinctive specimens resemble Stephenson's illustration of *C. smithvillensis* (1942, pl. 18, p. 108) more than that of *C. tombigbeensis*. However, it is identified with the latter on the basis of more than 30 anterior radial pore-canals (*C. smithvillensis* described as having 10, *C. tombigbeensis* 40) and its more deeply impressed, coarser pitting (see Stephenson, 1942, p. 113).

CLITHROCYTHERIDEA RUGATA
Schmidt, n. sp.
Plate 64, figures 27, 28

Description.—Carapace elongate-subovate in side view, highest at anterior cardinal angle, widest towards posterior. Dorsal and ventral margins subparallel, converging slightly posteriorly. Dorsal margin slightly convex, sloping posteriorly. Ventral margin straight to convex, somewhat sinuous just behind anterior ventral angle. Anterior margin broadly rounded, more oblique dorsally, and projecting somewhat below ventral margin. Posterior margin narrower, bluntly rounded. A row of small spines present on anterior, ventral, and posterior margins of right valve only. Surface slightly irregular, entirely covered with minute pits, giving granular appearance. On ventral side, granulations seem to be arranged in longitudinal parallel rows. Superimposed on them are scattered deeper and larger pits marking the position of normal pore-canals. Hinge and muscle-scar pattern characteristic of genus. Line of concrescence and inner margin apparently coincide, except in anterior ventral region, where inner margin is wide. Radial pore-canals numerous, 30 or more on anterior margin.

Dimensions.—Left valve, length, 0.78 mm.; height, 0.40 mm.; thickness, 0.20 mm.; right valve, length, 0.75 mm.; height, 0.36 mm.; thickness, 0.19 mm.

Cotypes.—U. S. National Museum 104-232 a, b, from sample G6.

Occurrence.—Rare in the Aquia formation (G6, 11).

Remarks.—This species resembles *C. tombigbeensis* and it might be mistaken for a more elongated dimorphic variety of superficially similar ornamentation. However, it differs markedly in outline and in the presence of denticulations on the right valve, and can be readily distinguished. The inner margin and line of concrescence do not coincide at anterior margin as in *C. tombigbeensis*. The irregular surface is also distinctive. It differs from *C. malkinae* mainly in the possession of a granular pitting.

CLITHROCYTHERIDEA MALKINAE
Schmidt, n. sp.
Plate 64, figures 24–26

Description.—Carapace tumid, subovate, thickest just behind center. Left valve more convex than right. Left valve larger, overlaps right on entire margin, more so ventrally and dorsally. Dorsal margin weakly arched, convex between obscure cardinal angles, highest over anterior cardinal angle. Dorsal margin forms an even curve with broadly rounded anterior margin, and well rounded though narrower posterior margin. Ventral margin straight to slightly convex, may be slightly sinuous. Surface smooth except for moderate pits which mark the position of normal pore-canals. Hinge and muscle-scar pattern characteristic of genus. Line of concrescence and inner margin coincide except at anterior end. Radial pore-canals numerous, 25 to 30 at anterior margin.

Dimensions.—Left valve, length, 0.61 mm.; height, 0.38 mm.; right valve, length, 0.61 mm.; height, 0.33 mm.; thickness, complete valve, 0.33 mm.

Holotype.—(Complete specimen) U. S. National Museum 104233 a, from sample G14; paratypes: (right and left valves) U. S. National Museum 104233 b, c, from sample G11.

Occurrence.—Common in the Aquia formation (C3, G11, 14).

Remarks.—This species differs from *C. rugata* mainly in its lack of fine granular surface pitting. In ornamentation it resembles *Haplocytheridea husseyi* and *H. goochi* of Stephenson, in that only large pits occur. However, the hinge and other characters definitely identify it with *Clithrocytheridea*. This species is named in honor of Doris S. Malkin of the Shell Oil Co.

CLITHROCYTHERIDEA VIRGINICA
Schmidt, n. sp.
Plate 64, figures 21–23

Description.—Carapace subpyriform to oblong in side view; tumid, highest at anterior cardinal angle. Valves subequal, left larger than right. Dorsal margin straight to slightly convex, slopes posteriorly in female. Ventral margin straight to slightly sinuous or concave, more so in right valve than left. Anterior margin rounded, strongly oblique, especially in dorsal half. Posterior end obliquely truncated, with rounded subacute posterior ventral angle, more marked in right valve. Entire surface irregularly and coarsely pitted, each pit generally marking site of normal pore-canal. A broad rounded ridge starts near middle of anterior margin, extends posteriorly and dorsally along anterior and dorsal margins, and dies out near middle of posterior margin. An irregular depression occurs below and subparallel to ridge. A prominent almost oval depression below mid-center of valve extends posteriorly and dies out at postero-ventral angle. A prominent rounded ridge of varying width separates this depression from the subparallel marginal depression and ridge, and is continuous with the narrower raised ventral border of the depression. Hinge, muscle-scar, and other internal features characteristic of genus.

Dimensions.—Male, left valve, length, 0.65 mm.; height, 0.32 mm.; female, left valve, length, 0.56 mm.; height 0.33 mm.; right valve, length, 0.61 mm ; height, 0.33 mm.; complete specimen (not figured) thickness, 0.30 mm.

Holotype.—U. S. National Museum 104-234 a, paratypes 104234 b–d, from sample G5.

Occurrence.—Common in the Aquia formation (C2, G5, 11).

Remarks.—The thickness of the ridges and depressions varies slightly because of irregularity in the coarse surface pitting. The male differs from the female in having almost subparallel dorsal and ventral margins, and being slightly longer.

This species differs from a specimen described by Swain in manuscript in that the "small node-like swelling" on ridge is lacking and the arrangement of the anterior ridge and groove, and median furrow and ridge, are different.

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CRETACEOUS ASTEROIDS FROM CALIFORNIA[1]

J. WYATT DURHAM
Department of Paleontology, University of California, Berkeley, California
AND
WAYNE A. ROBERTS
Los Angeles, California

WHILE examining the strata exposed in a roadcut along the North Fork of Matilija Creek, Ventura County, California, the junior author made an unusual paleontologic discovery. In an otherwise barren sequence of shales he uncovered a colony of fossil starfish, a group of animals that are very poorly represented in the North American Mesozoic and Cenozoic fossil record. At the time of the original discovery only a few fragmentary specimens were collected. Later after the importance of his find had been recognized, the junior author made a second trip to the locality and collected additional material. Subsequently the senior author visited the locality but no additional specimens were collected. In all, material representing over 35 individuals of *Astropecten* and one specimen of *Henricia* was collected.

The regional geology of the area has previously been mapped in a reconnaissance manner and the general stratigraphic succession established by Kerr and Schenck (1928). According to their work, the fossil locality here described falls in the "Chico formation" of upper Cretaceous age (*loc. cit.*, fig. 4a). Inasmuch as no fossils other than the ones here described have been found in the area by the authors the age of the present fossils is determined by Kerr and Schenck's work.

For comparison with the present species, a search of the literature has been made for references to North American Jurassic, Cretaceous and Cenozoic asteroids and their relatives, the ophiuroids. Thirty-three citations were found in which there are 6 references to Jurassic species, 18 references to Cretaceous occurrences and 16 references to Tertiary records.

[1] Contribution No. 413, Balch Graduate School of the Geological Sciences, California Institute of Technology, Pasadena, California.

The Jurassic records are very few, only two species of asteroids have been described. These are *Asterias* (?) *dubium* Whitfield (1877) and *Astropecten pĕwĕi* Miller and Unklesbay (1943).

The following asteroids have been recorded from the Cretaceous of North America:

Astropecten (?) *montanus* Douglas (1903)
Colorado shale, Upper Cretaceous, Montana.
Austinaster mc-carteri Adkins (1928)
Austin chalk, Upper Cretaceous, Texas.
Comptonia wintoni Adkins (1920)
Pawpaw sandstone, Lower Cretaceous, Texas.
Metopaster hortensae Adkins and Winton (1920)
Pawpaw sandstone, Lower Cretaceous, Texas.
Metopaster tennesseensis Wade (1926)
Ripley formation, Upper Cretaceous, Tennessee.
Pentaceros americanus Adkins (1920)
Pawpaw sandstone, Lower Cretaceous, Texas.
Pentagonaster browni Weller (1905)
Fox Hills sandstone, Upper Cretaceous, Wyoming.
Pentagonaster texensis Adkins and Winton (1920)
Weno Clay, Lower Cretaceous, Texas.
Genus and species undescribed, Whiteaves (1903)
Nanaimo Group, Upper Cretaceous, British Columbia.

In addition to the asteroids, the following ophiuroids have been recorded from the Cretaceous:

Amphiura lymani Waring (1917)
Chico formation, Upper Cretaceous, California.
Ophioderma (?) *bridgerensis* Meek (1873)
Colorado shale (?), Upper Cretaceous, Montana.
Ophioglypha[2] *graysonensis* Alexander (1931)
Grayson marl, Lower Cretaceous, Texas.
Ophioglypha texana Clark (1893)
Denison formation, Lower Cretaceous, Texas.
Ophioglypha n. sp. *a* Packard (1916)
Chico formation, Upper Cretaceous, California.
Ophiura travisana Berry (1941a)
Kemp clay, Upper Cretaceous, Texas.

[2] The generic name *Ophioglypha* should be replaced by *Ophiura* (Berry, 1941a, p. 62).

"Ophiuroids" Adkins (1928)
Various levels of Washita Group, Upper Cretaceous, Texas.
"Vertebral ossicles" Vanderpool (1933)
Upper Trinity Group, Lower Cretaceous, Texas.

With the two species here described, there are 10 described and one undescribed species of Asteroidea and five described and at least three undescribed species of Ophiuroidea known from the Cretaceous of North America. In contrast, there are 44 species of Asteroidea and seven species of Ophiuroidea recorded from the Cretaceous of the British Isles (Sladen, 1891, 1893; Spencer, 1905, 1907). Most of the British species have been found in the Cretaceous chalks. Most of the American species have been found in the Cretaceous of Texas, but there does not seem to be any restriction to a particular lithology.

In contrast to the asteroids and ophiuroids recorded from the American Cretaceous the following is a list of the species recorded from the Tertiary:

ASTEROIDEA

Asterias remondii Gabb (1869)
Lower San Pablo formation (Clark, 1915, p. 417), Miocene, California.
Asterias (?) sp. Morton, (Clark and Twitchell, 1915) Eocene, South Carolina.
Goniaster mammilata Gabb (1876)
Vincentown sand, Lower Eocene,[3] New Jersey.
Pentaceros asperulus Clark (in Weller, 1907)
Vincentown sand, Lower Eocene,[3] New Jersey.
Starfish plates, Howe (1942, fig. 18)
Chickasawhay formation, upper Oligocene, Mississippi.
Starfish plates, Howe (1942)
Vicksburg group, Oligocene, Gulf Coast.
Starfish plates, Howe (1942)
Jackson formation, Eocene, Gulf Coast.
Starfish plates, Howe (1942)
Jackson formation, Eocene, Georgia.
Starfish plates, Howe (1942)
Choctawhatchee formation, Miocene, Florida.

OPHIUROIDEA

Amphiophiura oligocenica Berry (1937)
Byram Marl, Oligocene, Mississippi.
Amphiura sanctaecrucis Arnold (1908)
Santa Margarita formation, Upper Miocene, California.
Amphiura (?) sp. Clark (1918)
Markley formation, Upper Eocene (referred to Oligocene at time of description), California.

[3] When these two species were described, the Vincentown sand was referred to the Upper Cretaceous, it is now considered to be of lower Eocene Age (Cooke, Gardner, and Woodring, 1943).

Ophioderma sp. Clark (1904)
St. Marys formation, Miocene, Maryland. (Same ? as *Ophiura marylandica*, Berry, 1934, p. 26).
Ophiomusium stephensoni Berry (1942)
Vincentown sand, Lower Eocene, New Jersey.
Ophiura marylandica Berry (1934)
St. Marys formation, Miocene, Maryland.
"Basket fish" Howe (1942, figs. 23, 24)
Jackson formation, Eocene, Alabama.
Ophiuran, Howe (1942, fig. 9)
Jackson formation, Eocene, Alabama.
Ophiuroid sp. Durham (1944)
Blakeley formation, Upper Oligocene, Washington.
Ophiuroid spp. Merriam (1931)
Records an ophiuran limestone from Santa Margarita formation, Upper Miocene, California. In addition makes reference to occurrences in the "Eocene"; "lower zone of the San Pablo Upper Miocene of Contra Costa County"; and "upper Miocene of Carneros Creek, 3 miles west of Napa, California."

Besides the preceding, the following ophiuroids have not previously been recorded in the literature:

Ophioglyphus (?) sp. (Univ. Calif. Mus. Pal., no. 11060, loc. 1318), Briones fm., Calif., Miocene.
Ophiuroid sp. (Calif. Acad. Sci., loc. 27789)
Santa Margarita fm., Calif., upper Miocene (not the same as *Amphiura sanctaecrucis* Arnold).
Ophiuroid sp. (Univ. Calif. Mus. Paleo. no. 11067, loc. A-715) Umpqua fm., Ore., Eocene.

A summary of the above North American Tertiary records shows that there are three described and at least six undescribed species of Asteroidea known, and four described and at least 11 undescribed species of Ophiuroidea known.

As Howe has indicated (1942) the remains of both ophiurans and asteroids may be rather abundant in certain sediments. From the data assembled by Howe, and from the other references in the literature, it appears probable that both groups are much better represented in the fossil record than the few described species might lead one to believe. Probably most workers have passed by the disarticulated plates, not recognizing the organisms represented, and therefore having no further interest in them.

In addition to the material recorded above, it is worth noting that Berry (1935, 1941b) has recorded a number of species of ophiuroids from the Tertiary of Venezuela and Trinidad.

DESCRIPTION OF CIT LOCALITY 1679

The outcrop in which the fossils were found, is 6.3 miles northeast along the road from Wheeler Springs, on the highway from Ojai to the Cuyama Valley. Referring to the 1942 reprint of the 1903 edition of the Mt. Pinos, Calif. Quadrangle (scale 1:125,000) topographic map, the locality appears to be in the SE¼ of the SE¼ of Sec. 2, T 5 N, R 23 W, Ventura County, California. The fossils were found in the middle part of a large cut along the northwest side of the road at a point just past the northeast end of a smaller cut on the southeast side of the road. The large cut occurs about ¼ mile southwest along the road from a point where it crosses a small canyon with a spring in it. The beds are dipping at a high angle in the cut and transect the face of the cut at a rather large angle. The fossil layer is associated with more massive beds than those characteristic of the shale a short distance on either side. The sediments in general are well bedded, dark greenish black, silty shales, indicated as belonging to the Chico formation by Kerr and Schenck (1928). The shales contain many fragments of leaves and a few small pockets of carbonized plant material, both above and below the fossiliferous layer. The echinoderms were found only on the adjacent surfaces of two beds where they were in contact with one another along the bedding plane, further the starfish appeared to be restricted to a very limited area on the surfaces, as they disappeared up dip. Possibly some may remain if the bedding plane is followed back into the outcrop. Other parts of the same surface were covered with irregular trails and markings, probably of invertebrate origin, but no other identifiable fossils were noted. Collector: Wayne A. Roberts, April 19th and May 4th, 1947.

PRESERVATION

The material collected appears to represent more than 35 individuals of *Astropecten* and one of *Henricia* (*?*). Many individuals are represented only by fragments, due to the breaking up of the fossiliferous bed during collecting, and the fact that the bed could not be followed into the cliff face with the equipment at hand. All specimens occur as molds in a silty, olive gray, micaceous shale, containing a layer of plant fragments from 2 to 10 mm. from the asteroid layer. The asteroids occur on the surface of a bedding plane and penetrate into the surface of each of the adjacent beds to variable depth up to 3 mm. No trace of the fossils was found within the rocks of the individual beds, nor in any adjacent beds. The conditions requisite for the preservation of the asteroids were apparently confined to the particular interval represented by the bedding plane separating the two beds and to a limited area on that surface. The surface of the bedding plane is marked by irregular undulations, suggesting ripple marks and various other small irregularities. The suggested ripple marks, the irregular surface of the bedding plane, and the plant fragments (rushlike as far as determinable) suggest "shallow" water deposition, probably in depths of less than 100 meters, and perhaps near the low tide mark. Clark (1946, p. 72) says that the 14 Australian species of *Astropecten* are "shallow water" forms, but two other genera of the family are represented by "deep water" species. Sladen (1889, p. 198) recorded species of *Astropecten* from depths of 2–450 fathoms, with most of the species from depths of less than 50 fathoms.

The individual molds vary from very well preserved to some in which only generalized structure is apparent. These poorer molds can in most cases be shown to represent the impression of individuals that were largely preserved in the surface of the opposing bed. The well preserved molds appear in three forms: one representing the oral surface; one representing the aboral surface; and one representing the aboral surface with the paxillae and integument completely removed so that the aboral surface of the ambulacral plates is exposed. The form of the mold appearing for a particular specimen appears to depend first on whether or not the individual was right side up or overturned; and second, the accidents of uncovering the impression determined whether or not the remains of the dorsal plates and integument were removed and the upper surface of the ambulacral plates visible. Where the remains of the paxillae have not been removed, the paxillae and integument have been superimposed on the upper surface of the ambulacral plates, so that the ambulacral

plates can be seen, but less clearly (and cleanly) than in the other two types of molds.

The impressions of the oral surface can be separated from the others by the clean and smooth appearance of the ambulacral plates, by the appearance of the adambulacral plates (which are rarely visible in the aboral impressions), and by the downward projecting oral plates. The aboral impression (where the dorsal plate and integument have not been removed) shows the madreporite (in complete specimens), and the upper impression of the oral plates projects upwards. In some of the impressions the ambulacral plates are still arched as in life, in others they have been flattened out. A cross-section of the arm of the genotype of *Astropecten*, showing the relationship of the various plates is given by Clark (1913, fig. 349).

All illustrations have been made by making a latex cast of the original mold and photographing it, rather than photographing the original mold which would have resulted in a reversed illustration.

ORIENTATION OF SPECIMENS IN MATRIX

Examination of the orientation of the specimens in the matrix shows no alignment of any sort. Approximately the same number of individuals are right side up as are overturned. There are no indications of any type of distribution, the individuals are apparently heterogenously scattered over the surface. Most specimens have the arms fully extended, but a few have them bent back on themselves, so that part of the oral and part of the aboral surface of a single arm can be seen at the same time.

DESCRIPTION OF SPECIES

Phylum ECHINODERMATA
Class ASTEROIDEA
Order PHANEROZONIA
Family ASTROPECTENIDAE
Genus ASTROPECTEN Gray

GRAY (1840), Ann. Mag. Nat. History, vol. 6, p. 180; CLARK (1946), Carnegie Inst. Washington, Pub. 566, pp. 72–73.

Genotype: *Asterias aranciaca* Linnaeus (subs. desig. Fisher, 1908).

The present species is referred to the genus *Astropecten* because the superomarginal and inferomarginal plates, although not equal, are of approximately equal size in lateral view, and apparently form vertical lateral faces to the ray, while the adambulacral plates are in contact with the inferomarginals throughout the ray and the aboral surface is covered with paxillae. The excentric madreporite precludes referring the species to the genus *Archaster*.

ASTROPECTEN MATILIJAENSIS
Durham and Roberts, n. sp.
Plate 65, figures 1–5; plate 66, figures 2, 4, 5

Rays 5, average radius of rays 26.5 mm., average radius of disk 8.2 mm., average width of ray at base 8.2 mm. Rays moderately slender, tapering gracefully, most rapidly so at base, to an acute tip. Interbrachial arcs acute. Margins of rays vertical, formed by superomarginal and inferomarginal plates, one above the other and corresponding in number and position. On different specimens the number of marginal plates appears to vary from about 23 to 31, but the apparently low counts are probably due to poor preservation. The most complete rays (on paratypes nos. 4861, 4864, and 4868) appear to have 30 to 31 marginal plates, but even on these the preservation of the tip is not perfect and there may be one or two additional plates. The aboral surface was apparently covered by an integument studded with numerous fine paxillae (paratypes nos. 4859, 4862, 4867), and apparently a few spines in the interbrachial areas. The precise character of the upper surface of the paxillae is not evident, but they do not appear to have been studded with numerous modified spinelets as in most modern Astropectens (Sladen, 1889, pls. 37, 38). The madreporite is about one third the radius of the disk in from the margin, moderately large, and well preserved on some specimens (paratypes nos. 4859 and 4869 especially). In position and character it is similar to that of *Astropecten pectinatus* Sladen, but is comparatively larger.

On the oral surface the ambulacral grooves are moderately wide. The ambulacral plates are bounded by adambulacral plates and both correspond in number and position to the inferomarginal plates except in the interbrachial areas and near the

mouth. Apparently there are five more ambulacral plates than inferomarginals. The interbrachial area is occupied by about eight small subpolyhedral (in equatorial section) plates, of variable size, with the largest about twice the size of the smallest.

The superomarginal plates are approximately equal in height to the inferomarginals, but in other respects they do not correspond. The ratio of the longitudinal (length of ray) to lateral dimensions in equatorial section is about 3:4. The height of these plates is approximately the same as the longitudinal dimension. The surface of the superomarginal plates appears to be ornamented by very numerous minute pits without any apparent order, and there is no evidence of any spines.

The inferomarginal plates on the holotype have a longitudinal to lateral dimension ratio of about 3:10 but on paratype no. 4861 it does not appear to be much more than about 3:6. However it is not believed that this variation is sufficient to be of specific value. In the interradial area the inferomarginal plates have a more nearly triangular shape with a base to altitude ratio of 3:10 where the base corresponds to the longitudinal dimension. The surface of these plates is similar to that of the superomarginals, and in addition there are laterally at least one small and two larger spines (obscurely shown on parts of the holotype, and moderately well shown on paratypes no. 4859, 4860, and 4867). These spines are finely fluted and have a length apparently about three-quarters that of the lateral dimension of the corresponding plate. The two larger spines are about equal in size while the smaller one has a diameter about half that of the larger ones but is nearly as long. The diameter of the larger spines is slightly less than half the width of the corresponding plate.

The adambulacral plates are smaller than either the infero- or superomarginal plates. They are roughly rectangular in shape and have a longitudinal to lateral dimension ratio of 2:3. Those adambulacral plates in an interradial position become triangular shaped as with the marginals. The surface of the adambulacral plates appears to have several tubercles or seats for spines, but no spines were found in place. A few detached spines on the impression of the aboral surface appeared as if they might have originally been attached to the adambulacrals and subsequently forced into their present position, but there is no surety of this.

The ambulacral plates are elongately triangular in shape when seen in an oral view, with the apex pointing away from the axis of the ray. The base to altitude ratio is approximately 2:7. The longitudinal vertical section of the ambulacral plate is triangular, while the lateral vertical section appears to be trapezohedral. When seen from the aboral view the plate is somewhat dumb-bell shaped. On the oral surface the plate has a triangular depression which extends laterally from the center of the ray to the vertex of the plate.

The mouth plates are elongately subtriangular shaped, with at least seven conical spines (paratypes nos. 4863, 4868) which increase slightly in length from the outermost to the innermost. The longest or innermost spines are about 1.5 times as long as the shortest spines and are about the same length as the largest inferomarginal plate spines. These spines are fine fluted and apparently circular in cross-section.

A plate that may be the ocular is discernible on one ray of paratype no. 4868. It appears almost spherical in shape with a diameter three to four times the longitudinal dimension of the adjacent superomarginal plates.

EXPLANATION OF PLATE 65

FIGS. *1–5*—*Astropecten matilijaensis* Durham and Roberts, n. sp. *1*, Paratype no. 4867, ×2.5, note spines on inferomarginal plates, madreporite, and upper and lower surfaces on two twisted arms. Marginal plates and spines of a second individual at extreme right. *2*, Paratype no. 4859, ×1.80, aboral surface, note numerous small paxillae appearing as granules. *3*, Two of poorer impressions adjacent to ray of holotype, ×1.3. *4*, Holotype no. 4858, ×1.8, oral surface. *5*, Paratype no. 4860, ×2.2, aboral surface, integument and paxillae largely removed, ambulacral plates arched. (p. 435)

Durham and Roberts, Cretaceous Asteroids

Durham and Roberts, Cretaceous Asteroids

In paratype no. 4860 most of the aboral integumental covering has been removed and the rays apparently were not flattened during fossilization. In this specimen (preserved so that the aboral surface is seen) the ambulacral plates are arched, presumably as in life, making an angle of about 150° with one another, except adjacent to the mouth where it is about 120°. Most specimens have been flattened during preservation and in those that show least evidence of further distortion (as in the holotype, and paratype no. 4859) it appears that the ambulacral, adambulacral, and marginal plates were all slightly inclined towards the tip of the ray, usually at an angle of about 70° with the axis of the ray.

Some specimens, for example paratype no. 4864, have the rays much more rounded. This may have been the outline of the animal during life, or it may be that the flattened impressions like the holotype and paratype no. 4859 represent more nearly the true shape in life. If this latter is the case, then specimens like paratype no. 4865 must represent individuals which had died some time previous to burial and had their rays somewhat rolled up before interment. At first it was thought that these individuals represented another species, but upon careful examination it was seen that they had the same number of marginal plates, and these plates are the same shape as in individuals like the holotype, so it was concluded that they are distorted individuals of the present species.

Types.—In the California Institute of Technology Paleontological Collections, holotype no. 4858; paratypes nos. 4859–4865, 4867, 4868. In addition there are the fragments and poorly preserved impressions representing the remaining 25 specimens which have not been assigned type numbers. Plaster casts of all the numbered specimens have been deposited with the U. S. National Museum and in the Museum of Paleontology of the University of California at Berkeley, Calif. Unfortunately part of the mold of the ambulacral area of the holotype was destroyed during the making of the casts. Fortunately the photographs used in illustrating it, and an excellent latex impression of it were taken before it was damaged.

Astropecten pewei Miller and Unklesbay (1943) from the Jurassic Sundance formation of Wyoming does not appear to be closely related to the present species; it has fewer and differently shaped marginal plates.

Order SPINULOSA
Family ECHINASTERIDAE
Genus HENRICIA Gray

Henricia GRAY (1840), Ann. Mag. Nat. Hist., vol. 6, p. 184; CLARK (1946), Carnegie Inst. Washington, Pub. 566, p. 148.

Genotype: *Henricia oculata* Gray = *Asterias sanguinolenta* Müller

HENRICIA (?) VENTURANA Durham and Roberts n. sp.
Plate 66, figures 1, 3

This species is represented by both oral and aboral impressions of a single individual. Unfortunately the details are not consistently well preserved, but it is believed that sufficient characters are preserved to warrant giving it a specific name. The disc is very small in comparison to the length of the arms. The arms are more or less gracefully curved, both the oral and aboral surfaces are represented. The margins of the arms are not distinct but it is believed that this is due to a lack of conspicuous marginal plates. However on one ray of the aboral mold, the integument has been removed and the aboral surface of the ambulacral plates is exposed and in this particular area the ambulacral plates appear to terminate laterally against vertical plates which might represent marginal plates.

Rays 5, radius of rays about 40 mm., radius of disk about 5 mm. Rays slender, width at base about 6.8 mm., tapering grace-

EXPLANATION OF PLATE 66

FIGS. *1, 3*—*Henricia venturana* Durham and Roberts, n. sp. Holotype no. 4866. *1*, oral surface no. 4866a, ×1.7. *3*, aboral surface no. 4866b, ×1.8. (p. 437)

2, 4, 5—*Astropecten matilijaensis* Durham and Roberts, n. sp. *2*, Paratype no. 4868, ×1.8, aboral surface. *4*, Paratype no. 4867, ×11, madreporite (retouched), *5*, Paratype no. 4864, ×2.45, oral surface, note contracted state of arms. (p. 435)

fully to tip. Interbrachial arcs acute. Margin of rays uncertain, probably rounded, marginal plates not conspicuous. The ambulacral plates occupy over one-half the width of oral surface of rays. It is suspected that this is due to flattening during fossilization. Aboral surface covered by a coarse granular network, possibly a few traces of short spines near the margins of the rays. Apparently about 35 ambulacral plates to a ray. Tube feet pores large, about 0.8 mm. in longitudinal diameter, adambulacral plates apparently corresponding to ambulacrals, not spinose, apparently about as long as wide. Madreporite dorsal, on margin of disk, about 1.5 mm. in diameter, surface marked by numerous vermiform radiating ridges.

Holotype, California Institute of Technology Paleontological Collections, nos. 4866A (oral surface), 4866B (aboral surface). Plaster casts have been deposited with the U. S. National Museum, and in the Museum of Paleontology of the University of California at Berkeley, Calif.

The reference of this species to the genus *Henricia* is very uncertain because of the apparent wide ambulacral grooves and lack of adambulacral spines, but it is possible that this is an apparent condition produced by flattening during fossilization. If, as suggested on the arm showing the aboral surface of the ambulacral plates, there are conspicuous marginals bounding the ray, the species might better be assigned to *Linckia* which may also have granular adambulacral plates.

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ADDITIONAL CONODONTS FROM THE SWEETLAND CREEK SHALE OF IOWA

WALTER YOUNGQUIST AND A. K. MILLER
State University of Iowa, Iowa City, Iowa

ABSTRACT—Representatives of 14 conodont genera (including 11 new species) are illustrated and described from three localities in the general vicinity of the type section of the Sweetland Creek shale of southeastern Iowa. At all of these places, the fauna is of much the same generic composition and differs only in detail.

RECENTLY we published in this JOURNAL a study of the conodont fauna that occurs in the type section of the Sweetland Creek shale about 4 miles east of Muscatine, in southeastern Iowa. In order to ascertain the distribution and relative abundance of the various genera and species in the formation and to secure any additional forms that might not have been represented in the type section for ecological or geographic reasons, we collected material at several other localities. Inasmuch as this formation is of very local occurrence in Iowa, our collecting was necessarily confined to a radius of some 2 miles from the type section. Only about nine good exposures are known, and all of them yielded conodonts. However, appreciable assemblages were found at only three places: (1) 2½ miles east of Muscatine (SW cor. sec. 21, T. 77 N., R. 1 W), (2) 2½ miles east and ¼ mile north of Muscatine (NW ¼ SW ¼ sec. 21, T. 77 N., R. 1 W), and (3) 4 miles east and ½ mile north of Muscatine (SW ¼ NE ¼ sec. 27, T. 77 N., R. 1 W.).

At all three of these localities, the fauna is abundant and varied and is clearly that of the type section with only minor variations. All together, we now have representatives of the following sixteen conodont genera from the Sweetland Creek shale:

Ancyrodella
Ancyroides
Angulodus
Bryantodus
Ctenognathus?
Euprioniodina
Hibbardella
Hindeodella
Ligonodina
Lonchodina
Lonchodus
Nothognathella
Palmatolepis
Polygnathus
Prioniodus
Synprioniodina

In addition, Branson and Mehl (1938, p. 158) have reported *Icriodus* from this formation, but none of our collections contain representatives of that easily recognized genus.

The new material, on which this report is based, has not altered our conclusions in regard to the age and affinities of the conodont fauna that occurs in the Sweetland Creek shale. That is, we are of the opinion that the formation is referable to the Upper Devonian and is approximately contemporaneous with the Grassy Creek shale of Missouri, which has yielded a very similar conodont fauna.

Small spheroidal bodies, like those that have been illustrated and described by Stauffer (1935, p. 620, pl. 75, figs. 54–56; 1940, p. 434, pl. 59, figs. 74–78) from the Ordovician and the Devonian of the Upper Mississippi Valley, occur in the Sweetland Creek shale and are abundant at the locality about 4 miles east and ½ mile north of Muscatine, Iowa. They appear to be composed of the same material as conodonts, with which they occur in direct association. Furthermore, their abundance in any given sample is in general directly proportional to the number of conodonts, which, however, are far more numerous. Stauffer identified these structures as "egg cases?"; but he was careful to add that their "exact nature" and "possible significance is still unknown, but their general appearance, composition and occurrence with the conodonts suggests that they may belong to these animals." Another possibility is that they are otoliths.

Acknowledgement is due to Dr. H. G. Hershey and Dr. S. E. Harris of the Iowa Geological Survey who have facilitated our work on this project. The photographs which accompany this report were retouched by Mr. Howard E. Webster of Iowa City. The Graduate College of The State Uni-

versity of Iowa made the completion of the study financially possible.

SYSTEMATIC PALEONTOLOGY

ANCYRODELLA NODOSA Ulrich and Bassler
Plate 68, figures 13, 14

Ancyrodella nodosa ULRICH and BASSLER, 1926, U. S. Nat. Mus. Pr., vol. 68, art. 12, pp. 44, 48, pl. 1, figs. 10–13.
Ancyrodella nodosa HOLMES, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 6.
Ancyrodella nodosa BRANSON and MEHL, 1944, *in* Shimer and Shrock, Index fossils of North America, p. 244.

The specimen represented by figure 13 is strikingly similar to the syntype of this species represented by Ulrich and Bassler's text figure 5 (8) and figures 10, 11 on their plate 1 of 1926. The other specimen that we are illustrating is somewhat less symmetrical and less attenuate posteriorly, but it falls well within the limits of the species.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa (pl. 68, fig. 13); and about 2½ miles east and ¼ mile north of Muscatine (pl. 68, fig. 14). Also lower Attica shale of New York.

Figured Specimens.—State University of Iowa, 5581 (pl. 68, fig. 13); 5582 (pl. 68, fig. 14).

ANCYROIDES CALVINI Miller and Youngquist
Plate 68, figure 16

Ancyroides calvini MILLER and YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 504, pl. 75, fig. 4.

Plate, which consists of three subequally developed lobes, is moderately convex orally, but one of the posterior lobes is rather strongly curved aborally. Blade is composed of about four denticles.

Remarks.—The lobes of the plate of this individual are not quite as short and blunt as are those of the holotype. The blade, however, as in that specimen, is almost median on the anterior lobe of the plate and is very low anteriorly. The plate, as in most representatives of this genus, is rather thick.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. The holotype came from the type section of the same formation, which is about 4 miles east of Muscatine

Figured Specimen.—State University of Iowa, 5583.

ANCYROIDES ORNATISSIMUS, Youngquist and Miller, n. sp.
Plate 68, figure 18

Oral surface of plate is moderately convex and nodose. On the stouter posterior lobe of the plate, a submedian row of confluent nodes forms a carina, whereas on the other posterior plate lobe there is a carina, which consists of nodes that are so prominent as to be spinose or denticular in form. The blade is large and consists of about seven denticles. The aboral surface of the plate bears three subequal keels and a small escutcheon.

Remarks.—The oral surface of this form is considerably more ornate than is that of any other known representative of the genus. Perhaps the most distinctive character of the species is the denticle-like nodes on the narrower of the posterior lobes of the plate. These processes are reminiscent of those that occur on *Ancyrognathus iowaensis* Youngquist of the Upper Devonian near North Liberty, Iowa.

Occurrence.—Sweetland Creek shale about 2½ miles east and ¼ mile north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5584.

ANCYROIDES PRINCEPS Miller and Youngquist
Plate 68, figure 20

Ancyroides princeps MILLER and YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 505, pl. 75, figs. 2, 3.

We are illustrating a single representative of this species, the genotype of *Ancyroides*. One of the posterior lobes of its plate is incomplete. The blade consists of about eight denticles, and it is definitely marginal in position. Otherwise, this individual does not appear to differ materially from the type specimens.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. The holotype and the paratype of this species are from the type section of the same formation, which is about 4 miles east of Muscatine.

Figured Specimen.—State University of Iowa, 5585.

ANCYROIDES? RUDIS Youngquist, and Miller, n. sp.
Plate 68, figure 19

The only known representative of this species is incomplete posteriorly. However, the longer of the posterior lobes of the plate appears to have been bifid before its distal portion was broken away, that is, the carina in this lobe bifurcates and so does the corresponding keel on the aboral surface. Both the bifurcated carina and the carina on the smaller posterior lobe of the plate are coarsely nodose. The lateral areas of the plate, however, do not bear nodes. The blade is large, and it consists of about seven denticles. It is located near one margin of the anterior lobe of the plate. Posteriorly the blade has a semblance of abrupt termination (as in typical *Ancyroides*) but nevertheless it is continued as a low denticulate ridge which joins with the carinae of the posterior lobes of the plate. Aboral surface of plate bears three small keels (one of which is bifid) and a small escutcheon.

Remarks.—This form is so different from all previously described species with which we are familiar that even its generic affinities are uncertain. Specific comparisons would therefore be superfluous.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5586.

ANCYROIDES UDDENI Miller and Youngquist
Plate 68, figure 15

Ancyroides uddeni MILLER and YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 505, pl. 74, fig. 16; pl. 75, fig. 5.

The figured specimen is similar in all respects to the holotype of this species.

Occurrence.—Sweetland Creek shale about 2½ miles east and ¼ mile north of Muscatine, Iowa. The type specimens of this species came from the type section of the same formation, which is about 4 miles east of Muscatine.

Figured specimen.—State University of Iowa, 5587.

ANGULODUS sp.
Plate 67, figure 17

The genus *Angulodus* is represented in our collections from the Sweetland Creek shale by only one specimen that seems to merit illustration. Neither of the terminations of this individual is complete, but the preserved part of it resembles rather closely typical representatives of the genus. Satisfactory specific comparisons are, however, not possible.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Figured specimen.—State University of Iowa, 5588.

BRYANTODUS AEQUALIS Youngquist, and Miller, n. sp.
Plate 68, figure 5

Bar arched orally and bowed laterally, and its inner margin flared laterally to form a shelf-like structure that is non-nodose. There are six subequal denticles on each limb of the bar, essentially all of them are inclined posteriorly, and they are confluent except near their distal ends. The cusp is fairly short and stout for this genus. On the outer aboral margin of the bar there is a small node near the point of cusp insertion and both anterior and posterior to it is a small marginal keel. Aboral surface broadly excavated.

Remarks—This species is in general similar to *B. bryanti* Stauffer of the Olentangy shale of Ohio but differs in the number of denticles. The specific name is given in reference to the fact that the denticles anterior to the cusp are equal in number to those posterior to it.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5589.

BRYANTODUS BICORNIS Youngquist, and Miller, n. sp.
Plate 67, figures 6, 7

This form belongs to a group of species of the genus *Bryantodus* in which the cusp is

about equalled in size by a single large adjacent denticle. As a matter of fact it is difficult if not impossible to distinguish the two in some cases.

The rest of the denticles on both of the bar limbs in this species are about equal in size. There are about five to seven denticles on each bar limb; they are subcircular in cross section, and they are closely appressed and are confluent throughout most of their length. The bar is gently bowed and more strongly arched. Aborally there is a well developed keel and only a small escutcheon.

Remarks.—This form is smaller than all of the closely similar species with which we are familiar. The specimen represented by figure 7 is designated as the holotype. That illustrated by figure 6 is incomplete posteriorly.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Types.—State University of Iowa, 5590 (holotype), 5591 (paratype).

BRYANTODUS BICRISTATUS Youngquist and Miller, n. sp.
Plate 67, figure 16

Posterior bar limb of holotype is incomplete, but preserved portion indicates that it was considerably shorter and smaller than the other bar limb. Anterior bar limb prominently keeled, carries about nine erupted denticles that are somewhat unequal in size, and in addition there are several large intercalated germ denticles in the general vicinity of the cusp. On both sides of the bar, there is a median lateral ridge which is particularly prominent and marginally nodose near the junction of the two bars.

Remarks.—This species resembles *B. bicornis* and *B. eximus*. The former is much smaller and neither it nor the latter has any germ denticles. However, in many features these three forms are very similar, and *B. eximus* and *B. bicristatus* are particularly close.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ miles north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5592.

BRYANTODUS EXIMUS Youngquist and Miller, n. sp.
Plate 67, figure 15

Bar strongly arched but very slightly bowed. Anterior bar limb is distinctly longer than posterior limb and prominently keeled. There are about nine short rounded denticles on each bar limb, and near the junction of the limbs is a large cusp and one large denticle adjacent to it. On the outer side of the bar there is a longitudinal lateral ridge; a comparable ridge on the inner side of the bar is markedly flared laterally in the vicinity of the cusp and is nodose marginally.

Remarks.—This species resembles *B. bicornis*, a smaller form, and *B. bicristatus*, which has several large intercalated germ denticles and erupted denticles that are unequal in size.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5593.

BRYANTODUS FLABELLATUS Miller and Youngquist
Plate 67, figure 21

Bryantodus flabellatus MILLER and YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 506, pl. 73, fig. 23.

The representative of this species that we are illustrating resembles the holotype very closely. However, it is slightly larger than that specimen, and the adoral margins of its bar are not so prominently expanded laterally.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. The holotype of this species came from the type section of the same formation, which is about 4 miles east of Muscatine.

Figured specimen.—State University of Iowa, 5594.

BRYANTODUS MASCULUS Youngquist and Miller, n. sp.
Plate 68, figure 4

Holotype is rather large for this genus and is moderately arched and bowed. Bar is laterally compressed but its inner oral margin is expanded laterally to form a narrow shelf-like process which is non-nodose. Cusp

is large and though rounded laterally is subangular anteriorly and posteriorly. Anterior denticles, which are ten in number, are laterally compressed. There are about six denticles posterior to the cusp and they are rounded. Aboral side strongly keeled.

Remarks.—This form is fairly typical of the genus *Bryantodus*, as now generally interpreted. However, it is not particularly close to any of the numerous representatives of that genus that have been illustrated and described.

Occurrence.—Sweetland Creek shale about 2½ miles east and ¼ mile north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5595.

BRYANTODUS NITENS Youngquist and Miller, n. sp.
Plate 68, figure 1

This species is based on a specimen that is exceptionally well preserved and is complete with the exception of the tip of one denticle. Holotype is moderately bowed and arched. Bar is thick and laterally expanded to form a ridge-like process on both its inner and its outer sides. The ridge on the outer side is finely nodose marginally, and near the point of cusp insertion it bears a single large rounded node which extends aborally. On the inner side both the margin and the oral surface of this ridge are finely nodose. Cusp large, essentially circular in cross section, and only slightly inclined posteriorly. "Plane" of denticles is somewhat sinuous. Except at anterior end of holotype, denticles show a progressive decrease in size posteriorly. Aboral surface of bar slightly keeled near anterior and posterior extremities, but its mid-portions are essentially flat.

Remarks.—The holotype of *B. prosseri* Stauffer of the type section of the Olentangy shale at Delaware, Ohio, is somewhat similar to the species under consideration. However, it is more prominently keeled posteriorly and does not bear a prominent node near the point of cusp insertion.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5596.

BRYANTODUS STRATFORDENSIS Stauffer
Plate 68, figure 3

Bryantodus stratfordensis STAUFER, 1938, Jour. Paleontology, vol. 12, pp. 412, 423, pl. 48, fig. 17; pl. 49, fig. 6.

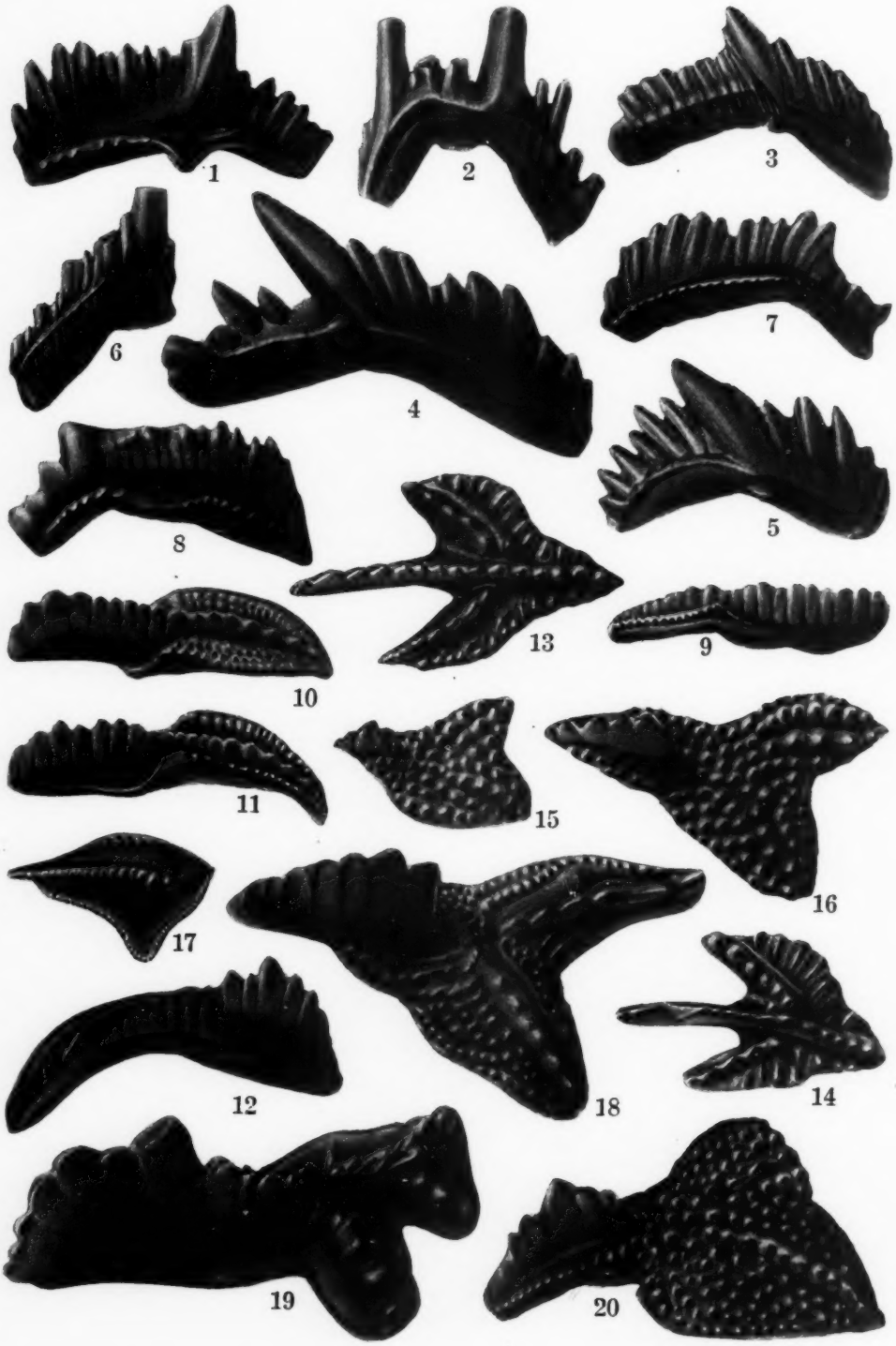
Our specimen seems to be strikingly similar to the holotype of this species. As in that individual, the largest denticle is immediately adjacent to the cusp; posterior to the cusp the denticles are deeply inserted whereas anteriorly they originate high in the bar, and germ denticles are especially well developed immediately posterior to the cusp.

EXPLANATION OF PLATE 67

All specimens illustrated on this plate (with the exception of figures *18*, *19*) are from the Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. Figures *18*, *19* are from the same formation about 2½ miles east and ¼ mile north of Muscatine. The illustrations are ×40.

FIGS. *1*, *2*—*Prioniodus alatus* Hinde. (p. 449)
3—*Prioniodus* cf. *P. remus* Stauffer. (p. 449)
4—*Hindeodella milleri* Stauffer. (p. 445)
5—*Nothognathella? abnormis* Branson and Mehl. (p. 447)
6, *7*—*Bryantodus bicornis* Youngquist and Miller, n. sp. Paratype and holotype. (p. 442)
8, *9*—*Bryantodus* sp. (p. 445)
10—*Hindeodella* sp. (p. 446)
11, *12*—*Ligonodina* sp. (p. 446)
13—*Lonchodina brevipennata* Branson and Mehl. (p. 446)
14—*Lonchodus parallelus* Cooper. (p. 447)
15—*Bryantodus eximus*, Youngquist and Miller n. sp. Holotype. (p. 443)
16—*Bryantodus bicristatus* Youngquist and Miller, n. sp. Holotype. (p. 443)
17—*Angulodus* sp. (p. 442)
18—*Bryantodus* sp. (p. 445)
19—*Hibbardella* sp. (p. 445)
20—*Hindeodella* sp. (p. 446)
21—*Bryantodus flabellatus* Miller and Youngquist. (p. 443)

Youngquist and Miller, Late Devonian Conodonts



Youngquist and Miller, Late Devonian Conodonts

Occurrence.—Sweetland Creek shale about 2½ miles east of Muscatine, Iowa. The holotype came from the type section of the Olentangy shale in Ohio.

Figured specimen.—State University of Iowa, 5597.

BRYANTODUS spp.
Plate 67, figures 8, 9, 18

The two specimens represented by figures 8 and 9 resemble each other closely but do not seem to be very similar to any described species. However, they may be related to *B. notatus* Huddle of the New Albany shale of Indiana.

The individual illustrated by figure 18 may be immature. At least superficially it resembles *B. simplex* Branson and Mehl of the Grassy Creek shale of Missouri.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa (figs. 8, 9); and about 2½ miles east and ¼ mile north of Muscatine (fig. 18).

Figured specimens.—State University of Iowa, 5598 (figs. 8, 9), 5599 (fig. 18).

HIBBARDELLA sp.
Plate 67, figure 19

Only very small portions of the three bar limbs are preserved on this specimen. The cusp is large, considerably compressed, and sublenticular in cross section. The escutcheon is triangular in shape with its apices extending toward the three bar limbs.

Occurrence.—Sweetland Creek shale about 2½ miles east and ¼ mile north of Muscatine, Iowa.

Figured specimen—State University of Iowa, 5600.

HINDEODELLA MILLERI Stauffer
Plate 67, figure 4

Hindeodella milleri STAUFFER, 1938, Jour. Paleontology, vol. 12, pp. 412, 428, pl. 50, figs. 1, 3a, 3b, 4, 9–11.

The specimen that we are referring to this species has a thin bar that is slightly arched orally and considerably bowed laterally. The cusp is deeply inserted in the bar, and the two diameters of its cross section are essentially equal. The anterior denticles also are deeply inserted in the bar, but the posterior ones seem to more or less grade into bar material. The denticles are closely appressed, and they constitute an alternating series in which there are two to four small ones between adjacent large ones—the size-difference between the large and the small denticles is not marked.

EXPLANATION OF PLATE 68

All specimens illustrated on this plate are from the Sweetland Creek shale at three localities near Muscatine, Iowa—those represented by figures *3* and *12* are from 2½ miles east of Muscatine; those by figures *2, 4, 6, 8, 14, 15, 18* are from 2½ miles east and ½ mile north of Muscatine; and those by figures *1, 5, 7, 9–11, 13, 16, 17, 19, 20* are from 4 miles east and ½ mile north of Muscatine. The illustrations are ×40.

FIG. *1*—*Bryantodus nitens*, Youngquist and Miller, n. sp. Holotype. (p. 444)
2—*Lonchodina bilateralis* Ulrich and Bassler. (p. 446)
3—*Bryantodus stratfordensis* Stauffer. (p. 444)
4—*Bryantodus masculus* Youngquist and Miller, n. sp. Holotype. (p. 443)
5—*Bryantodus aequalis* Youngquist and Miller, n. sp. Holotype. (p. 442)
6—*Synprioniodina* sp. (p. 449)
7—*Nothognathella bicristata* Youngquist and Miller, n. sp. Holotype. (p. 447)
8—*Nothognathella brachyodonta* Youngquist and Miller, n. sp. Holotype. (p. 447)
9—*Polygnathus* sp. (p. 449)
10—*Polygnathus multinodosa* Youngquist and Miller, n. sp. Holotype. (p. 448)
11—*Polygnathus normalis* Miller and Youngquist. (p. 448)
12—*Polygnathus longipostica* Branson and Mehl. (p. 448)
13, 14—*Ancyrodella nodosa* Ulrich and Bassler. (p. 441)
15—*Ancyroides uddeni* Miller and Youngquist. (p. 442)
16—*Ancyroides calvini* Miller and Youngquist. (p. 441)
17—*Palmatolepis subrecta* Miller and Youngquist. (p. 448)
18—*Ancyroides ornatissimus* Youngquist and Miller, n. sp. Holotype. (p. 441)
19—*Ancyroides? rudis* Youngquist and Miller, n. sp. Holotype. (p. 442)
20—*Ancyroides princeps* Miller and Youngquist. (p. 441)

Remarks.—Our specimen appears to resemble rather closely the syntypes represented by figures 9 and 11 on Stauffer's plate 50 of 1938. This species seems to have been allowed considerable latitude.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. Also, Olentangy shale of Ohio and Ontario.

Figured specimen.—State University of Iowa, 5601.

HINDEODELLA spp.
Plate 67, figures 10, 20

The figured specimens seem to be referable to *Hindeodella*, although that shown in figure 20 is not typical of that genus. The smaller of these specimens has a fairly sharp keel. The anterior portion of its bar is twisted. This specimen is finely denticulate, and sporadic germ denticles are present in it. The cusp, which is located near the midportion of the preserved part of the specimen, is subcircular in cross section.

The bar of the larger specimen under consideration is considerably bowed and arched, and its anterior portion is twisted. There appears to be no recognizable cusp on this individual. Sporadic germ denticles are evident in it.

Remarks.—We do not believe that the two specimens discussed are closely related. The smaller of them is superficially somewhat similar to the syntype of *H. converta* represented by figure 22 on Stauffer's plate 50 of 1938. The concave (rather than the convex) side of the larger of our two specimens is illustrated.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa (both specimens).

Figured specimens.—State University of Iowa, 5602 (pl. 67, fig. 10), 5603 (pl. 67, fig. 20).

LIGONODINA sp.
Plate 67, figures 11, 12

Both of the specimens illustrated are incomplete and only a very small part of the anticusp is retained on them. However, the preserved portions suggest a relationship to such forms as *L. hindei* Ulrich and Bassler, particularly to the representatives of that species known from the lower Attica shale of New York and the New Albany shale of Indiana.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Figured specimens.—State University of Iowa, 5604 (pl. 67, fig. 11), 5605 (pl. 67, fig. 12).

LONCHODINA BILATERALIS Ulrich and Bassler
Plate 68, figure 2

Lonchodina bilateralis ULRICH and BASSLER, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 32, pl. 5, fig. 18.
Lonchodina bilateralis HOLMES, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 13.

The denticles of the holotype of this species are somewhat more nearly complete than are those of the specimen we are associating with it. However, comparable portions of these two individuals do not seem to differ significantly, and they are almost certainly conspecific.

Occurrence.—Sweetland Creek shale about 2½ miles east and ¼ mile north of Muscatine, Iowa. Also, lower Attica shale of New York.

Figured specimen.—State University of Iowa, 5606.

LONCHODINA BREVIPENNATA Branson and Mehl
Plate 67, figure 13

Lonchodina brevipennata BRANSON and MEHL, 1934 [1933], Missouri Univ. Studies, vol. 8, no. 3, p. 212, pl. 15, fig. 13.
Lonchodina brevipennata BRANSON and MEHL, 1944, *in* Branson, Missouri Univ. Studies, vol. 19, no. 3, p. 163.

Branson and Mehl illustrate an inner view of the holotype of this species, whereas our figure represents an outer view of a similar specimen, the curvature of which, however, is reversed. Although, our specimen is not quite as nearly complete as the holotype, it seems to resemble that individual very closely, except for a slight difference in relative length of the bar limbs.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. Also, Grassy Creek shale of Missouri.

Figured specimen.—State University of Iowa, 5607.

LONCHODUS PARALLELUS Cooper
Plate 67, figure 14

Lonchodus parallelus COOPER, 1939, Jour. Paleontology, vol. 13, p. 392, pl. 46, fig. 42.
Lonchodus parallelus MILLER and YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 511, pl. 72, fig. 14.

Although the specimen under consideration is not precisely similar to the holotype of this species or to the individual that has been illustrated from the type section of the Sweetland Creek shale, all three are probably conspecific. The bar of the specimen we are studying is particularly prominent and it is rectangular in cross section. Also, the single denticle that is preserved entire suggests that these structures may have been relatively short.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. Also, the type section of the same formation (that is, about 4 miles east of Muscatine), and a "Bushberg-Hannibal horizon" in Oklahoma.

Figured specimen.—State University of Iowa, 5608.

NOTHOGNATHELLA? ABNORMIS Branson and Mehl
Plate 67, figure 5

Nothognathella? abnormis BRANSON and MEHL, 1934 [1933], Missouri Univ. Studies, vol. 8, no. 3, pp. 231–232, pl. 14, figs. 1, 2.
Nothognathella? abnormis BRANSON and MEHL, 1944, *in* Branson, Missouri Univ. Studies, vol. 19, no. 3, p. 163.

Insofar as we can tell from the published illustrations and description of the syntypes, our specimen is quite similar to them. Near the posterior end of the inner side of the individual we are studying, there is a semblance of a platform that is very small. This structure indicates that Branson and Mehl's reference of this species to *Nothognathella* is probably correct.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. The type specimens came from the Grassy Creek shale of Missouri.

Figured specimen.—State University of Iowa, 5609.

NOTHOGNATHELLA BICRISTATA Youngquist and Miller, n. sp.
Plate 68, figure 7

The holotype is strongly arched and moderately bowed. Its cusp is of about the same size as the large denticle adjacent to it, and some of the denticles near the mid-length of the anterior portion of the specimen are as long or even slightly longer than the cusp. All denticles (and the cusp) are confluent almost to their apices. Platform is minutely nodose on its margins and oral surface. It is relatively narrow on the outer (figured) side but rather wide on the inner side. Aborally there is a small posterior keel, but the anterior keel is large.

Remarks.—This form exhibits certain of the characters that are generally regarded as typical of *Bryantodus* as well as certain of those of *Nothognathella*. We are referring it to the latter genus largely because of the pronounced laterally expanded platform-like development of its base.

The specimen illustrated by figure 7 on our plate 73 of 1947 may possibly belong in this species. It came from the type section of the Sweetland Creek shale, which is about half a mile south of the locality which yielded the above described holotype.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5610.

NOTHOGNATHELLA BRACHYODONTA Youngquist and Miller, n. sp.
Plate 68, figure 8

Specimen moderately arched and strongly bowed. Cusp and the few denticles preserved posterior to it on the holotype are short and stout. Denticles anterior to cusp are much more numerous, and they are short and closely appressed to form a stout blade. Platform, which is marginally nodose, is narrow on outer (figured) side but well developed on inner side. Aborally there is a flat central zone, but anteriorly and posteriorly moderate keels are present.

Remarks.—The holotype is incomplete posteriorly. In comparison to most other representatives of *Nothognathella*, this species has a relatively short stout blade.

Occurrence.—Sweetland Creek shale about 2½ miles east and ¼ mile north of Muscatine, Iowa.

Holotype.—State University of Iowa, 5611.

PALMATOLEPIS SUBRECTA Miller and Youngquist
Plate 68, figure 17

Palmatolepis subrecta MILLER AND YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 513, pl. 75, figs. 7–11.

The single representative of *Palmatolepis* that we are illustrating seems to be referable to *P. subrecta* Miller and Youngquist, though it is somewhat smaller than the syntypes of that species. The blade and its carinal continuation are fairly straight, and there is no carina on the lateral lobe of the plate. The oral surface of the plate is very finely nodose.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. The syntypes of this species are from the type section of the same formation, which is about 4 miles east of Muscatine.

Figured specimen.—State University of Iowa, 5612.

POLYGNATHUS LONGIPOSTICA Branson and Mehl
Plate 68, figure 12

Polygnathus longipostica E. B. BRANSON and MEHL, 1934 [1933], Missouri Univ. Studies, vol. 8, no. 4, p. 294, pl. 24, figs. 8–11, 13.
Polygnathus longipostica E. R. BRANSON, 1934 [1933], Missouri Univ. Studies, vol. 8, no. 4, p. 311, pl. 25, fig. 18.
Polygnathus longipostica E. B. BRANSON, 1938, Missouri Univ. Studies, vol. 13, no. 3, p. 182.
Polygnathus longipostica E. B. BRANSON and MEHL, 1938, Missouri Univ. Studies, vol. 13, no. 4, p. 132, pl. 33, fig. 53.
Polygnathus n.sp. KNECHTEL and HASS, 1938, Jour. Paleontology, vol. 12, p. 519.
Polygnathus longipostica COOPER, 1939, Jour. Paleontology, vol. 13, pp. 401, 420, pl. 39, figs. 31, 32, 43, 44.
Polygnathus longipostica HASS, 1943, Jour. Paleontology, vol. 17, p. 308.
Polygnathus longipostica E. B. BRANSON, MEHL, and E. R. BRANSON, 1944, *in* E. B. Branson, Missouri Univ. Studies, vol. 19, no. 3, p. 221, pl. 32, fig. 53.

Our collections contain a specimen that resembles very closely the syntype of this species represented by Branson and Mehl's figure 9 on their plate 24 of 1934. It seems to differ materially from that individual only in that its posterior portion has a somewhat stronger aboral curvature.

Occurrence.—Sweetland Creek shale about 2½ miles east of Muscatine, Iowa. Also, the Bushberg and Hannibal formations of Missouri and equivalent beds in Oklahoma, and, according to Hass, in "a thin unit of dark shale at the base of the Lodgepole limestone" of Montana.

Figured specimen.—State University of Iowa, 5613.

POLYGNATHUS MULTINODOSA Youngquist and Miller, n. sp.
Plate 68, figure 10

The specimen that serves as the holotype of this species is complete in every detail. There are about ten denticles in the blade, which is straight and rather high and thin. The carina, which joins the blade anteriorly, is prominently nodose, and extends essentially the length of the platform. Oral surface of platform is very slightly concave and prominently ornamented with small nodes. Aborally there are rather prominent anterior and posterior keels and, on the anterior third of the platform, a small (but well developed) escutcheon.

Remarks.—The most significant characteristic of this species seems to be the nearly flat platform with a nodose oral surface.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Holotype—State University of Iowa, 5614.

POLYGNATHUS NORMALIS Miller and Youngquist
Plate 68, figure 11

Polygnathus normalis MILLER and YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 515, pl. 74, figs, 4, 5.

The figured specimen is strikingly similar to the holotype of this species, having about nine denticles on the blade and having the posterior portion of the plate strongly curved aborally.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. The holotype and the paratype of this species came from the type section of the

same formation, which is about 4 miles east of Muscatine.

Figured specimen.—State University of Iowa, 5615.

POLYGNATHUS sp.
Plate 68, figure 9

This specimen is referable to the genus *Polygnathus*, and it is typical of numerous individuals in our collections from the Sweetland Creek shale. These specimens show a great deal of gradational variation, and they do not seem to possess characters that are particularly significant. They are in general similar to several forms that in 1938 Stauffer illustrated and described from the Olentangy shale of Ohio and Ontario, but they do not appear to be conspecific.

Occurrence—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa.

Figured specimen.—State University of Iowa, 5616.

PRIONIODUS ALATUS Hinde
Plate 67, figures 1, 2

Prioniodus? alatus HINDE, 1879, Quart. Jour. Geol. Soc. London, vol. 35, p. 361, pl. 16, fig. 5.
Prioniodus? alatus GRABAU, 1899, Buffalo Soc. Nat. Sci. Bull., vol. 6, p. 153.
Prioniodus? alatus GRABAU and SHIMER, 1910, North American Index fossils, Invertebrates, vol. 2, p. 243.
Prioniodus alatus GRABAU and SHIMER, 1910, North American Index fossils, Invertebrates, vol. 2. p. 244.
Prioniodus alatus BRYANT, 1921, Buffalo Soc. Nat. Sci. Bull., vol. 13, no. 2, pp. 15–16, pl. 3, fig. 10; pl. 4, figs. 1–7.
Prioniodus alatus ULRICH and BASSLER, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 11, pl. 1, figs. 25, 26.
Prioniodus alatus HOLMES, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 20, pl. 3, fig. 40.
Prioniodus alatus BRANSON and MEHL, 1933, Missouri Univ. Studies, vol. 8, no. 2, p. 134, pl. 11, fig. 13.
Prioniodus alatus HUDDLE, 1934, Bull. Am. Paleontology, vol. 21, no. 72, pp. 14, 21, 37, pl. 1, figs. 1–3.
Prioniodus alatus COOPER, 1939, Jour. Paleontology, vol. 13, pp. 404, 420, pl. 45, fig. 55, pl. 46, figs. 6, 8.
? Prioniodus cf. *P. alatus* HASS, 1943, Jour. Paleontology, vol. 17, p. 308.
Prioniodus alatus QUIGLEY, and MEHL and QUIGLEY, 1944, *in* Branson, Missouri Univ. Studies, vol. 19, no. 3, p. 158, pl. 27, figs. 42, 45, 46 [not 43, "47"].
Prioniodus alatus YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 111, pl. 26, fig. 11.
Prioniodus alatus HASS, 1947, Jour. Paleontology, vol. 21, p. 134.

Our collections contain two specimens that we are referring to this well known widespread species. The oral portion of the cusp is missing from both of them, but the remaining parts are sufficient to establish their affinities beyond reasonable doubt.

Remarks.—This form is readily differentiated from *P. bellatulus* by means of its closely appressed denticles.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa (both specimens). Also occurs in an Upper Devonian shale near North Liberty, Iowa, and in the Genesee and Portage groups of New York, the New Albany shale of Indiana, the Snyder Creek shale and the Sylamore sandstone of Missouri, and a "Bushberg-Hannibal horizon" in Oklahoma. Also reported from the Huron and lower Ohio shales of Ohio. *P. confluens* Branson and Mehl of the Grassy Creek shale of Missouri may be conspecific.

Figured specimens.—State University of Iowa, 5617 (pl. 67, fig. 1), 5618 (pl. 67, fig. 2).

PRIONIODUS cf. P. REMUS Stauffer
Plate 67, figure 3

? Prioniodus remus STAUFFER, 1940, Jour. Paleontology, vol. 14, p. 431, pl. 59, figs. 29, 37, 51, 53, 66.

The specimen we are studying agrees fairly well with Stauffer's syntypes in almost all of its characters, but the aboral margins of its cusp are not appreciably flared and the basal portion of the cusp is only slightly excavated. We are uncertain as to how much taxonomic significance should be attached to these differences. The distal portion of the anticusp of our specimen is missing.

Occurrence.—Sweetland Creek shale about 4 miles east and ½ mile north of Muscatine, Iowa. The syntypes of *P. remus* came from the Cedar Valley formation of southern Minnesota.

Figured specimen.—State University of Iowa, 5619.

SYNPRIONIODINA sp.
Plate 68, figure 6

This specimen is so incomplete that its affinities are very uncertain, but it seems to

be referable to *Synprioniodina* and to resemble *S. alternata* Ulrich and Bassler, which is widespread in the Upper Devonian and Lower Mississippian of this country. Our specimen has a finely denticulate anticusp, a large rounded cusp, and denticles that occur in series with one or two small denticles between adjacent large ones.

Occurrence.—Sweetland Creek shale about 2½ miles east and ¼ mile north of Muscatine, Iowa.

Figured specimen.—State University of Iowa, 5620.

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NEW CAMBRIAN TRILOBITE GENERA FROM NORTHWEST SONORA, MEXICO

CHRISTINA LOCHMAN
University of Chicago, Chicago, Illinois

ABSTRACT—Seven new trilobite genera and species of late Lower and early Middle Cambrian age are described. The necessity for recognizing the importance of facies in determining the generic composition of early Middle Cambrian faunas in the Cordilleran region is emphasized. The *Albertella* faunal assemblage is considered the earliest Middle Cambrian zone, and the validity of the *Kochaspis liliana* zone is questioned. It can now be shown conclusively that the next youngest Middle Cambrian zone must comprise both the abundant limestone facies fauna commonly referred to as the *Glossopleura-Kootenia* zone and the shale facies genera, *Zacanthoides* and *Anoria*. As *Glossopleura* is uninfluenced by facies changes and appears to range through the entire thickness of the zone, it is suggested that the term, *Glossopleura-Kootenia* zone, be used for the entire faunal assemblage.

DURING 1943 and 1944 a cooperative investigation of the Paleozoic stratigraphy of the Caborca area of Northwest Sonora, Mexico was undertaken by the Instituto Geológico de Méjico and the Smithsonian Institution (Cooper and Arellano, 1946). At the invitation of Dr. G. A. Cooper I studied the Cambrian material which was collected from this region. The finished report, which is now awaiting publication as a joint project of the two above mentioned Institutions, contains descriptions of all the Cambrian species found and gives full details of the stratigraphic relationships of the various faunas, the known vertical ranges of the genera and the generic compositions of the various faunal assemblages. In this paper, in order to expedite the study of Cambrian faunas, the new genera are described and certain pertinent information concerning Cambrian faunal zones and faunal assemblages is presented.

The fossil collections from the Caborca area revealed the presence of a considerable thickness of strata of Lower Cambrian and early Middle Cambrian age. In the Lower Cambrian faunal sequence the *Obolella* zone, the *Olenellus* zone and the *Antagmus-Onchocephalus* zone (Lochman, 1947) can be recognized. The faunal assemblages of these zones are all relatively small in numbers of genera and species; and only one new genus, *Sombrerella*—genotype *Sombrerella mexicana* n. sp.—is described. *Sombrerella* appears to be a small uncommon member of the *Antagmus-Onchocephalus* assemblage.

In the early Middle Cambrian faunal sequence I recognize the *Albertella* zone as carrying the earliest Middle Cambrian assemblage, and the *Glossopleura-Kootenia* zone the next higher major faunal assemblage. This study of the Mexican sections, an examination of the faunal lists from other Cordilleran Middle Cambrian sections and an examination of many described species at the United States National Museum have convinced me that certain misconceptions are present concerning the early Middle Cambrian zones as indicated on the Cambrian Correlation Chart (Howell, et al., al., 1944). The difficulty has arisen from two causes. The Middle Cambrian workers have attempted to maintain the details of local faunas in local sections in erecting their continent-wide zones. And they have failed to appreciate the importance of facies in determining the appearance and abundance of certain early Middle Cambrian trilobite genera. Thus *Albertella*, considered as alone diagnostic of a faunal zone, is represented throughout the Cordilleran region by hundreds of shale specimens, but I know of only twenty limestone specimens recorded to date. This feature is responsible for most of the confusion in the position of *Albertella*, as only where the fossils occur in abundance in the shales are they noted by field workers. However, the stratigraphic position of shale beds is known to vary in the Cambrian Cordilleran sections.

The determination of a faunal zone in the early Middle Cambrian must be based upon

a consideration of the entire faunal assemblage of that zone as revealed by a study of many sections representing all types of facies. In the limestone facies of the Mexican sections, the *Albertella* zone assemblage contains not only rare specimens of *Albertella* but also species of *Kochaspis*, *Strotocephalus*, *Dolichometopsis?* and three new genera, *Proveedoria*, *Mexicella* and *Mexicaspis*. The two last are of particular interest. *Mexicaspis*, represented by two species, is clearly closely related to *Albertella* and may possibly be a southern mutant of this genus adapted to a limy facies. *Mexicella* is represented by a single very abundant species which has a vertical range through the greater part of the zone in the Mexican sections. To this genus also belongs the closely related species originally described as "*Agraulos*" *stator* Walcott from British Columbia and Montana. I regard *Mexicella* as one of the most useful and important genera of the *Albertella* assemblage. The genus is now known to range throughout the Cordilleran region from British Columbia to Northwest Sonora and is represented by an abundance of individuals in both clastic and limestone facies.

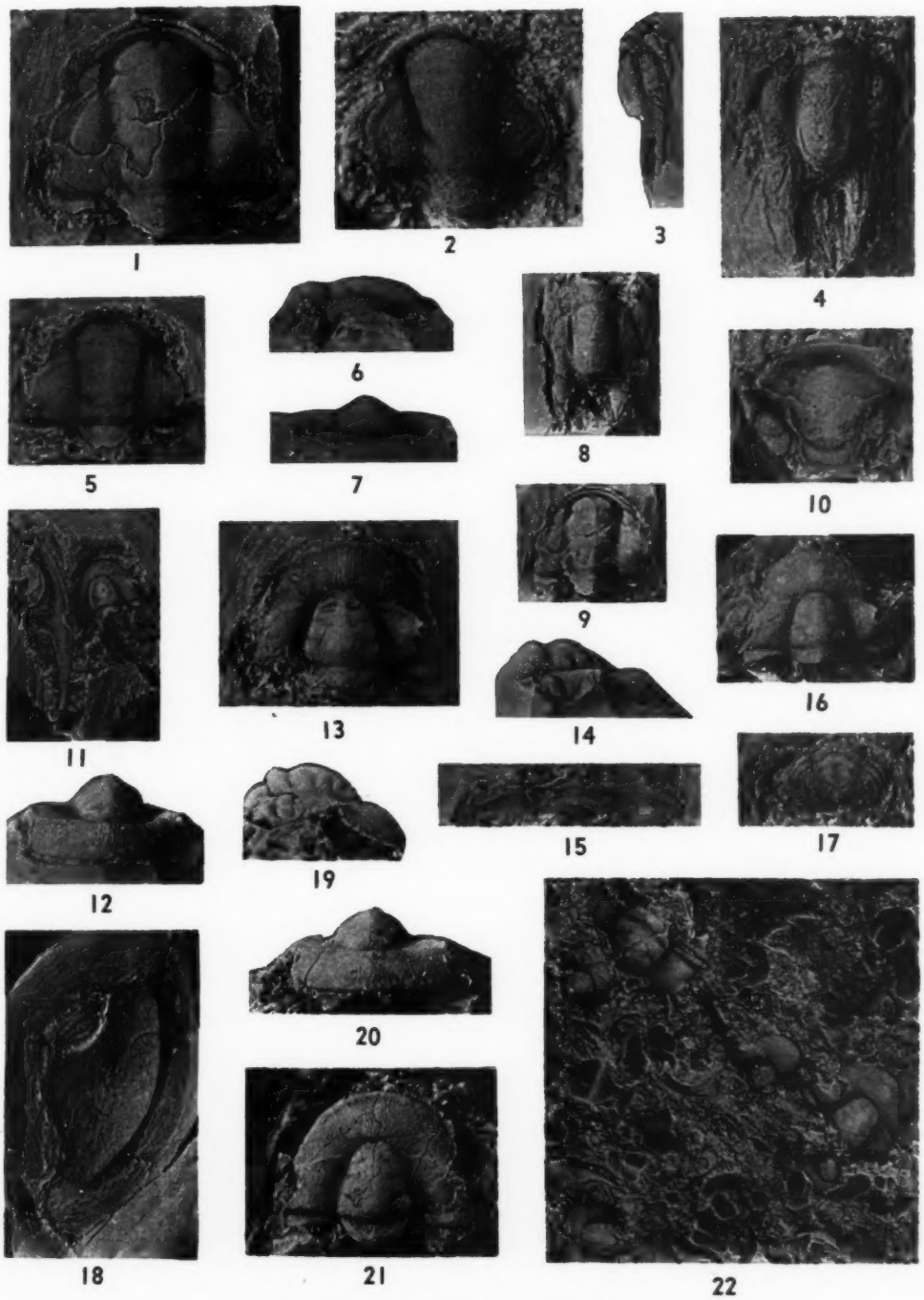
In the Cambrian Correlation Chart (Howell, et al., 1944) a *Kochaspis liliana* zone is recognized as containing the earliest distinct faunal assemblage of the Middle Cambrian. The term has little if any exact value since the species has been recorded only from the Nevada sections, and the genus *Kochaspis* apparently ranges through most of the Middle Cambrian. In the Mexican sections the uppermost Lower Cambrian and the basal Middle Cambrian strata are all predominantly limestone. This part of the section was examined carefully but no evidence of a zone characterized exclusively by any species of *Kochaspis* could be found. *Kochaspis* sp. undet. and *Strotocephalus* were the lowest Middle Cambrian fossils obtained and in the immediately overlying beds *Albertella* appears with *Kochaspis*. The latter genus continues throughout the collections from the *Albertella* zone as one of the less common members of the assemblage. Consequently, I must question the validity of the *Kochaspis liliana* zone, as neither from a study of the Mexican sections nor an examination of the literature have I been able to establish the existence of a distinct and independent faunal assemblage older than the *Albertella* assemblage in the basal Middle Cambrian beds.

The immediately succeeding faunal assemblage of the early Middle Cambrian is that of the *Glossopleura-Kootenia* zone containing *Glossopleura*, *Alokistocare*, *Kootenia*, *Pachyaspis*, *Anoria*, *Zacanthoides* and *Athabaskia* (the cited *Clavaspidella* of the Cordilleran region). I do not recognize the identity of a faunal zone characterized by the restricted occurrence of *Anoria* and *Zacanthoides*. These two genera, like *Albertella*, occur most commonly and conspicuously in shale beds, but in four widely separated localities they are now known to occur with recognized members of the *Glossopleura-Kootenia* fauna. In a Mexican section a few rare limestone specimens of *Zacanthoides* occur with *Alokistocare althea* (Walcott). In the Grand Canyon section (McKee and Resser, 1945) at Locality 19 *Anoria* occurs with *Glossopleura* and *Alokistocare althea* (Walcott) and at Locality 11 *Zacanthoides* occurs with *Kootenia* and *Pach-*

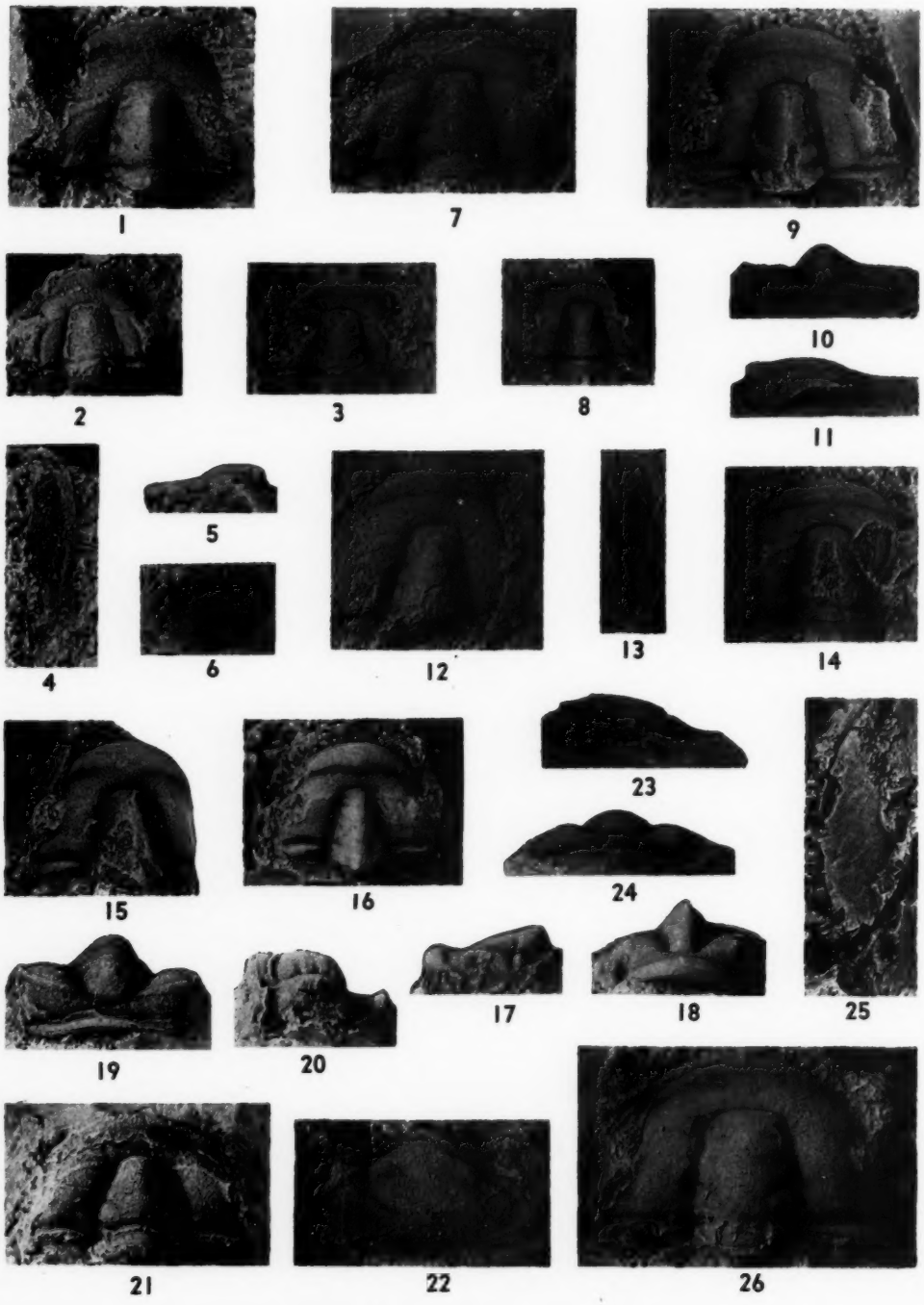
EXPLANATION OF PLATE 69

FIGS. *1–11*—*Mexicaspis stenopyge* Lochman, n. gen., n. sp. *1*, *9*, dorsal views of a nearly complete cranidium, ×2, ×1, coll. 801x; *2*, dorsal view of a distorted cranidium, ×6, coll. 800d; *3*, *8*, side and dorsal views of best preserved pygidium, ×2; *4*, dorsal view of a large pygidium, ×3; *5–7*, holotype, dorsal, side, and front views of a well preserved cranidium, ×5; *10*, ventral view of a hypostoma, ×4; *11*, an associated free cheek lying by a small cranidium of *Mexicella mexicana*, ×5, all from coll. 801x. (p. 455)

12–22—*Mexicella mexicana* Lochman, n. gen., n. sp. *12–14*, holotype, front, dorsal, and side views of a peeled cranidium, ×4; *16*, dorsal view of a small cranidium with outer surface preserved, ×4; *17*, an associated pygidium, ×10, all from coll. 802a; *15*, a thoracic segment, ×2; *19–21*, side, front, and dorsal views of a complete but peeled cranidium, ×4, coll. 801l; *18*, a large weathered free cheek, ×2, coll. 801j; *22*, a coquina of cranidia, ×4, coll. 802a. (p. 457)



Lochman, Cambrian Trilobites



Lochman, Cambrian Trilobites

yaspis. In Utah the Spence shale member of the Langston carries *Zacanthoides*, *Glossopleura*, *Alokistocare* and other genera (Williams and Maxey, 1941). In the British Columbia sections Deiss (1939, pp. 1017–1018) suggests that *Anoria* and *Athabaskia* are within the *Glossopleura* fauna. The association of all these genera in a single faunal assemblage must be recognized.

Of this assemblage *Glossopleura*, *Alokistocare* and, to a lesser extent, *Kootenia* appear to be the most valuable genera as they have no facies preference and are widespread in the Cordilleran region. *Glossopleura* ranges through the entire zone and *Alokistocare* has almost as long a range. Although a tabulation of the various species now referred to *Kootenia* shows a stratigraphic range from the Lower Cambrian nearly to the end of the Middle Cambrian, in the Cordilleran sections the appearance and abundance of *Kootenia* are undeniably a valuable aid in recognizing this zone. All the listed Lower Cambrian occurrences are from the Appalachian trough, and the late Middle Cambrian occurrences in the Cordilleran region can be shown to be misidentifications of the pygidia of *Olenoides*. Thus it would appear that *Kootenia* has a definite stratigraphic significance in western North America and at present I favor retaining the name in the zonal terminology.

From the *Glossopleura-Kootenia* assemblage three new genera are described: *Arellanella* (ārāyänĕllä), *Kistocare* and *Caborcella*. *Kistocare* shows relationships to both *Alokistocare* and *Alokistocarella*. *Caborcella* —genotype *Caborcella arrojosensis* n. sp.— is also known from the Cadiz formation of the Marble Mountains, California where a closely related species was originally described (Mason, 1935) as *Acrocephalites? trifossatus* Mason.

The generic descriptions are arranged by faunal zones to facilitate stratigraphic studies and emphasize faunal relations.

LIST OF LOCALITIES

North side of Cerro Prieto, 1–2 km. southwest of Caborca, Sonora

collection 809a—loose on north slope

Section on north side of Puerto Blanco, 6 miles due west of Caborca, Sonora

collection 801i—100 feet above base of Los Arrojos formation
collection 801j—cobbly beds 538 feet above base of Los Arrojos formation
collection 801k—625 feet above base of Los Arrojos formation
collection 801ka—716 feet above base of Los Arrojos formation
collection 801l—736 feet above base of Los Arrojos formation

Section on Los Difuntos, about 14 miles north-northwest of Caborca, Sonora

collection 802a—near base of west hill, 30–35 feet above valley floor
collection 802b—110 feet above valley floor

Section on west end of Arrojos Hills, 12 miles west-southwest of Caborca, Sonora

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EXPLANATION OF PLATE 70

FIGS. *1–6*—*Kistocare corbini* Lochman, n. gen., n. sp. *1*, dorsal view of cranidium showing surface granules, ×4, coll. 801n; *2*, *5*, holotype, dorsal and side views of small, nearly complete cranidium ×5; *3*, small cranidium with posterior limb, ×5; *4*, a fragmentary free cheek, ×5; *6*, a small pygidium, ×5, all from coll. 800c. (p. 463)

7–14—*Proveedoria starquistae* Lochman, n. gen., n. sp. *7*, dorsal view of large, broken cranidium, ×5; *8*, dorsal view of a small cranidium, ×5; *9–11*, holotype, dorsal, front, and side views of most complete cranidium, ×5; *12*, distorted cranidium obtained as a squeeze, ×5; *13*, a small free cheek, ×5; *14*, dorsal view of a weathered cranidium, ×5, all from coll. 801i. (p. 459)

15–18—*Sombrerella mexicana* Lochman, n. gen., n. sp. *15*, dorsal view of broken cranidium, ×5; *16–18*, holotype, dorsal, side, and front views of most complete cranidium, ×4, both from coll. 809a. (p. 454)

19–21—*Caborcella arrojosensis* Lochman, n. gen., n. sp. Holotype, front, side, and dorsal views of most complete cranidium, ×3, coll. 800c. (p. 461)

22–26—*Arellanella caborcana* Lochman, n. gen., n. sp. *22*, a large pygidium, ×5; *23*, *24*, *26*, holotype, side, front, and dorsal views of medium-size well preserved cranidium, *23* and *24*, ×3, *26*, ×4; *25*, a fragmentary free cheek, ×4, all from coll. 800a. (p. 460)

collection 800a—basal shale
collection 800c—260 feet above base of section at base of dark shale, N.W. side of largest hill

Lower Cambrian
Antagmus-Onchocephalus zone

SOMBRERELLA Lochman, n. gen.

Cranidium small, subquadrate; glabella conical with straight front, strongly convex, profile high posteriorly, sloping steeply down to front; three short glabellar furrows; occipital furrow narrow; occipital ring flat, narrow at side, expanding to center; a brim, a marginal furrow with suggestion of a median inbend, and a border present; anterior margin rounded. Fixed cheeks approximately ½ width of glabella, horizontal; palpebral lobes small, slightly forward of center; palpebral furrow shallow; ocular ridge narrow, well-defined; posterior limbs same width as occipital ring. Free cheek not known. Facial suture cutting anterior margin well out at sides, curving back to palpebral lobes; thence out and back to cut posterior margin within genal angle. Outer surface not known; inner surface punctate.

Thorax and pygidium not known.

Genotype.—*Sombrerella mexicana* Lochman, n. sp.

Generic Characters: Cranidium.—

1) Palpebral lobes small, located slightly forward of center of glabella but not as far as the anterior one-third.
2) Glabella narrowly conical with a median ridge, strongly convex; highest posteriorly dropping to very low anteriorly in a steep slope; glabellar furrows faint.
3) Fixed cheeks ½ width of glabella on midline
4) Fixed cheeks approximately horizontal in position
5) Posterior limbs equal in width to occipital ring
6) A brim, a marginal furrow, and a border

Remarks.—A new genus has been proposed for two small but distinctive cranidia which do not fit into any known genus. The question was considered as to whether the peculiar shape of the glabella and the narrow fixed cheeks, the two features, which in combination are responsible for its divergence, could in any way be caused by distortion. On the holotype there is a healed crack running the entire length of the right side, but it does not appear to have had any effect on the shape of the cranidium. The paratype has the top of the glabella broken, but all features of the cranidium check with those of the holotype. The genus appears to be a small, distinct form in this late Lower Cambrian fauna.

SOMBRERELLA MEXICANA Lochman, n. sp.
Plates 70, figures 15–18

Cranidium subquadrate, 4 mm. across eyes × 4½ mm. in length; glabella narrowly conical with straight front, strongly convex with appearance of a median ridge, profile highest posteriorly sloping steeply down to a very low anterior; three short, extremely faint, glabellar furrows; occipital furrow narrow, present at sides but nearly obsolete across center; occipital ring flat, narrow at sides, expanding rapidly to center with a node on posterior margin, in profile continuing upward slope of back of glabella so actually is highest part of cranidium; brim narrow, flat, sloping at sides, horizontal at center; marginal furrow broad, shallow, narrower toward center with a suggestion of a median inbend; border of medium width, moderately convex, horizontal; anterior margin rounded. Fixed cheeks approximately ½ width of glabella, horizontal; palpebral lobes small, slightly forward of center but not on anterior one-third of glabella; palpebral furrow shallow, faint; ocular ridge narrow, well-defined, slightly curved to just behind front of glabella; posterior limbs same width as occipital ring. Free cheek not known. Facial suture cutting anterior margin well out at sides, running out and back to marginal furrow, then back and in to and around palpebral lobes; thence curving out and back to cut posterior margin well within genal angle. Outer surface not known; inner surface with coarse punctations on brim and medium-sized punctations on fixed cheeks and posterior limbs.

Thorax and pygidium not known.

Remarks.—Only two small cranidia have been obtained to represent this genus and species. Its features appear distinctive and valid, but more specimens are needed. The broken glabella on the paratype suggests that this exposed portion of the cranidium was especially subject to damage. Moreover, although the top is gone, the glabella in the paratype does not seem quite so narrow and steep as in the holotype, so that some question still remains as to whether the extreme

appearance of the holotype may not be due to some slight distortion of the specimen which cannot now be detected.

Formation and Locality.—Lower Cambrian, Buelna limestone, collection 809a.

Types.—Holotype and paratype cranidia are deposited in the U. S. National Museum.

Middle Cambrian
Albertella zone

MEXICASPIS Lochman, n. gen.

Cranidium oblong-elongate; glabella oblong, sides nearly parallel posteriorly, slightly expanded in front; four pairs of glabellar furrows; dorsal furrow present, deepening into small pit opposite first glabellar furrow; occipital furrow well-defined; occipital ring triangular in shape, posterior median node or spine may be present; small rectangle brim in front of fixed cheek only; marginal furrow only at sides, merging into dorsal furrow; border generally narrow. Fixed cheek approximately one-half width of glabella on its midline; palpebral lobe of medium length, somewhat posterior to midline of glabella; ocular ridge weak; palpebral furrow broad, shallow; posterior limb same width as occipital ring with broad shallow furrow. Free cheek narrow, elongate; ocular platform widening posteriorly; marginal furrow present; border with a medium-length, slender genal spine. Facial suture cutting anterior margin far out at sides, curving out slightly, then running straight back to and around palpebral lobes; then curving out and back to posterior margin. Hypostoma subtriangular, expanded anteriorly into short, broad, downcurved lappets; anterior lobe large, oval; posterior lobe of medium width, crescentic; rim-like posterior border; slit-like macula at each side of anterior lobe; anterior border narrow, convex.

Thorax not known.

Pygidium rectangular in outline; sides straight or converging posteriorly; axis convex, nearly parallel-sided to border, with four or more segments, anterior ones with median axial node; dorsal furrow present; pleural lobes narrower than axis, a single anterior segment ending in a slender marginal spine, and the posterior pleural area extending into a heavier marginal spine; border and marginal furrow on posterior half of pygidium.

Outer surface of test finely granulated; inner surface minutely punctate.

Genotype—*Mexicaspis stenopyge* Lochman, n. sp.

Generic Characters: Cranidium.—

1) Palpebral lobes medium, just posterior to midline of glabella
2) Glabella oblong, nearly parallel-sided, expanding slightly at front; four pairs of glabellar furrows
3) Fixed cheeks approximately ½ width of glabella on midline
4) Fixed cheeks horizontal
5) Posterior limbs same width as occipital ring
6) Narrow rectangular brim in front of fixed cheek only, marginal furrow at sides only, narrow border

Thorax not known

Pygidium:

1) Axis prominent, nearly straight-sided, extending to border
2) Pleural lobes narrower than axis
3) First pleural segment extended into marginal spine; rest of pleural area extended into second marginal spine

Remarks.—*Mexicaspis* appears to be most closely related to *Albertella* in the structure of both the cranidium and pygidium, and I believe should be placed in the same family. *Mexicaspis* differs from *Albertella* in the following generic features: 1) palpebral lobes always medium-sized, just back of midline of glabella, 2) fixed cheeks one-half width of glabella, 3) posterior limbs same length as occipital ring, and 4) structure of the two pairs of marginal spines on the pygidium.

The two known species of *Mexicaspis* differ in several other details which are not considered of generic value: 1) the weak development of the ocular ridge, and 2) the more broadly triangular occipital ring.

MEXICASPIS STENOPYGE Lochman, n. sp.
Plate 69, figures 1–11

Cranidium oblong-elongate; glabella oblong, parallel-sided posteriorly, expanding moderately forward, slightly convex; glabellar and dorsal furrows practically obsolete on outer surface, well-defined on inner; four pairs of broad shallow glabellar furrows, first and second straight, very short, third arcuate, short, fourth arcuate, longer; dorsal

furrow broad, shallow, deepening into small pit opposite first glabellar furrow, shallow across front of glabella; occipital furrow broad, shallow; occipital ring broadly triangular, flat, no median node; brim a narrow sloping rectangle in front of fixed cheek; marginal furrow of medium width, very shallow, merging with dorsal furrow; border narrow, very slightly convex, band-like; anterior margin a flat curve. Fixed cheeks one-half width of glabella, slightly convex, horizontal; palpebral lobes of medium length, slightly arcuate, situated a little back of midline of glabella; ocular ridge broad, very faint; palpebral furrow broad, only on inner surface; posterior limbs of medium width and length, with a very broad shallow marginal furrow. Free cheek narrow, elongate, medium-size eye at inner angle; ocular platform narrow, flat anteriorly, becoming wider and steeply sloping posteriorly; marginal furrow broad, shallow; border of medium width, slightly convex, crossed by narrow ridges, with a short anterior projection and a long, slender genal spine. Facial suture cutting anterior margin far out at sides, curving out, then straight back to and around palpebral lobes; thence curving out and back to cut posterior margin within genal angle. Hypostoma subtriangular with broadly expanded anterior border and short, broad, curved lappets; anterior lobe oval, expanding anteriorly, moderately convex, with a prominent curved ridge at each posterior corner just below a shallow, slit-like macula; posterior lobe a small, convex crescent, separated from anterior lobe by a well-defined furrow which coalesces with the narrow posterior marginal furrow at the sides; narrow, rim-like posterior border; anterior border convex, narrow at center, expanding laterally into lappets, separated whole length from anterior lobe by anterior marginal furrow, deep and broad at center, shallow across lappets.

Thorax not known.

Pygidium elongate-oblong in outline; axis strongly convex, practically parallel-sided with bluntly rounded end, extending to border, divided into four or five segments and a terminal portion by furrows, anterior two broad and deep, rest faint and narrow; a median axial node may be present on first two segments; dorsal furrow shallow; pleural platforms two-thirds width of axis, divided by one broad, deep interpleural groove into one broad anterior segment extending backward into a long slender marginal spine, and an unmarked triangular area continuing posteriorly into a short, stout marginal spine; the lateral margins converge posteriorly so that the posterior pair of spines are quite close together and extend straight back; a medium-wide, flat border set off by a faint, shallow marginal furrow around posterior half; posterior margin very short, straight to slightly concave.

Outer surface of test thickly covered with fine granules; inner surface minutely punctate.

Remarks.—This species is represented by a large number of cranidia and pygidia and several hypostoma and free cheeks from two horizons, both in limestone. Although leaching by ground water has damaged the surface of most of the specimens of this species, it was chosen in preference to the other species occurring in this collection because the greater number of specimens afford a better concept of the various parts of the carapace and the size range to be expected in the species.

Formation and Locality.—Middle Cambrian, Los Arrojos formation, collections 8011, 801ka, 800d.

Types.—Holotype and paratypes, cranidia, pygidia, free cheeks and hypostoma are deposited in the U. S. National Museum.

MEXICELLA Lochman, n. gen.

Cephalon elongate-ovate; cranidium nearly quadrangular; glabella short, conical with straight front; three pairs of short glabellar furrows; dorsal furrow present; occipital furrow present; occipital ring expanding somewhat medially; brim usually wide, convexity variable; border usually much narrower; marginal furrow usually faint; anterior margin curved. Fixed cheeks slightly narrower than glabella, almost horizontal; palpebral lobes small, situated anterior to midline of glabella; ocular ridge strong, slightly arcuate; palpebral furrow obsolete; posterior limb moderately wide, usually same length as occipital ring. Free cheek triangular, small eye at inner angle; ocular platform relatively wide; faint marginal furrow; narrow border with short

pointed anterior projection and a blunt rounded genal angle with a tiny genal node at outer corner in some species. Facial suture cutting anterior margin about half-way out, curving out and back to marginal furrow, then running generally straight back to and around palpebral lobes; thence curving out and back to posterior margin. Hypostoma not known.

Thorax of 22 narrow segments; axis convex; pleural lobe moderately convex, one and one-half times width of axis, each segment crossed by a broad shallow pleural furrow and with a short, bluntly pointed end.

Pygidium small, transverse, convex longitudinally; axis wide, flat, two-thirds length of pygidium; dorsal furrow present; pleural lobes narrower than axial; both marked by one or two anterior segments; border present.

Outer surface of test finely granulated; inner usually coarsely punctate.

Genotype.—*Mexicella mexicana* Lochman, n. sp.

Generic Characters: Cranidium.—

1) Palpebral lobes small, very slightly forward of midline of glabella
2) Glabella short, length and width approximately equal, conical with straight front; three pairs of short glabellar furrows
3) Fixed cheeks 9/11ths the width of glabella
4) Fixed cheeks very slightly downsloping
5) Posterior limbs approximately same width as occipital ring
6) Brim wide, with or without median bulge; faint marginal furrow; usually a narrow border

Remarks.—This genus is established for *M. mexicana* Lochman, n. sp. and the closely related species *M. stator* (Walcott) from the Ross Lake shale member of the Cathedral formation of British Columbia. *M. stator* was first described as *Agraulos stator* and was later placed by Resser (1935) in *Alokistocare*. The diagnosis of *Alokistocare* and all the species placed in it to date reveals that, while these two species are fairly close to *A. subcoronatum* (H. and W.) in many features of the cranidium, they differ consistently in a) the small size and the position of the palpebral lobes, and b) the greater width of the fixed cheeks. No especially marked difference in the ends of the thoracic pleura, as mentioned by Resser, could be detected. *Mexicella* has a very different type of frontal median bulge from that of *Alokistocare*. In *Mexicella* it is simply a very broad low elevation on the brim, apparently caused by an increase in convexity in one part of the brim, and is absent in immature cranidia and very inconspicuous in *M. stator*. In *Alokistocare* the bulge is centered on the marginal furrow and spreads on to both the brim and border, and is very distinct.

The presence of a minute genal node at the outer corner of the squared genal angle of *M. mexicana* is very interesting as it suggests the last vestige of a genal spine. Its very small size causes it to be easily overlooked or broken off, and more effort should be made to look for such features in genera which appear to have a smooth genal angle.

MEXICELLA MEXICANA Lochman, n. sp.
Plate 69, figures 12–22

Cephalon slightly oval in outline; cranidium square; glabella short, squat, conical with a straight front, moderately convex posteriorly and sloping down rapidly anteriorly, glabella only very slightly longer than brim and border; three pairs of fairly well-defined glabellar furrows, first pair narrow slits, straight or slightly slanted, set in from dorsal furrow, second pair diagonal, third pair arcuate, both on outer third of glabella; dorsal furrow well-defined, broad at sides, narrow across front; occipital furrow broad, deep at sides, shallow across center; occipital ring of medium width, expanding slightly at median line, with a small occipital node; brim wide, convex, with a low broad median bulge (not found in cranidia under 3 mm. in length); border semicircular, narrow, convex, barely distinguished in adults by a faint narrow marginal furrow on inner surface of test; anterior margin broadly rounded. Fixed cheeks wide, slightly less than width of glabella, flat; palpebral furrow very faint; palpebral lobes small, slightly curved, situated slightly in front of midline of glabella; ocular ridge prominent, curved; posterior limbs short, of medium width, with a narrow marginal furrow. Free cheek triangular in outline, steeply sloping, with small eye at inner angle; ocular platform and border indistinguishable in small cheeks, but in larger ones a faint marginal furrow separates off a

narrow border with a long pointed anterior projection and a squared genal angle with a minute node at outer corner. Facial suture cutting anterior margin half way out, curving gently out to edge of border, then back and straight in to and around palpebral lobes; then curving out around and slightly in to cut posterior margin within genal angle.

Thoracic segments narrow; axis rather strongly convex, apparently with a small median axial node on each segment; pleural lobes one and one-half times width of axis, flat near dorsal furrow, then moderately downsloping, with a short, backward turned point on end; pleural furrow shallow, broad; number of segments not known.

Pygidium small, strongly convex longitudinally, transverse; axis wide, nearly flat, tapering rapidly, about two-thirds length of pygidium, crossed by one or two narrow furrows forming two narrow anterior segments and a wide terminal portion; dorsal furrow narrow, well impressed at sides, faint around end; pleural platforms narrower than axis, strongly convex, divided into two segments by narrow interpleural grooves; border of medium width, flat, nearly horizontal at sides, becoming vertical behind.

Outer surface of test of pygidium, fixed cheeks and glabella sprinkled with small granules; the heavy anastomosing venation of inner surface radiating across brim shows through on outer surface of well preserved specimens; inner surface coarsely punctate. In immature cranidia the outer surface appears quite smooth. One free cheek shows four or five alternating low nodes and pits along base of ocular platform.

Remarks.—This species is extremely abundant in the earliest Middle Cambrian faunas (the *Albertella* zone assemblage) in the Mexican sections. In horizon 802a it is represented by cranidia ranging from the protaspid to small holaspid stages. From horizon 801j one fragmentary cranidium is 13 mm. in length and two free cheeks correspond to cranidia 24 mm. in length. The great abundance of smaller cranidia suggests that they represent molts. The earliest holaspid stages more resemble the species *M. stator* in the apparent absence of the median bulge and lessened convexity of the glabella.

In the U.S.N.M. material *M. stator* is represented not only by the types in shale but also by some limestone specimens, slightly worn and distorted, from the same section. There are also some cranidia in sandstone, simply labeled *Agraulos*, from U.S.N.M. Locality 150d—White Creek, Powell Co., Montana—which show exactly the same specific features as *M. stator*.

The two species appear to be closely related but can be distinguished by: 1) in *M. mexicana* the glabella is much more convex, and the curvature of the brim is stronger near the glabella, while in *M. stator* the curvature is gentler and more even and continuous; and 2) in *M. stator* the fixed cheeks seem to be very slightly wider in proportion to the glabella than in *M. mexicana* but this feature may be due to slight mechanical flattening in the *M. stator* specimens.

Formation and Locality.—Middle Cambrian, Los Arrojos formation, collections 801j, 801k, 801ka, 801l, 802a, 802b, 800d.

Types.—Holotype and paratypes, cranidia, pygidia, thoracic segments and free cheeks are deposited in the U. S. National Museum.

PROVEEDORIA Lochman, n. gen.

Cranidium subquadrate; glabella conical, somewhat longer than wide, with nearly straight front, convex; three pairs of glabellar furrows; dorsal furrow present; occipital furrow present; occipital ring of medium width, subtriangular; brim present; a marginal furrow; border present with a very shallow groove transversely through the center; anterior margin curved. Fixed cheeks two-thirds width of glabella, slightly upsloping; palpebral lobes of medium size, situated almost on posterior one-third line of glabella; a faint palpebral furrow present; faint ocular ridge present; posterior limb narrow, same length as occipital ring, crossed by a narrow, well-defined marginal furrow. Free cheek short, narrow, with medium sized eye at inner angle; ocular platform of medium width, downsloping; marginal furrow present; border narrow, flat with a short pointed anterior projection and a short flat genal spine. Facial suture cutting anterior margin well out at side, curving back, then into and around palpebral lobes; thence curving out and back to cut posterior margin within genal angle.

Thorax and pygidium not known.

Outer surface of test covered with fine granules, with narrow imbricating ridges on border of cranidium and free cheek; inner surface not known.

Genotype.—*Proveedoria starquistae* Lochman, n. sp.

Generic Characters: Cranidium.—

1) Palpebral lobes medium-sized, almost but not quite on posterior one-third line of glabella
2) Glabella regular conical, somewhat longer than wide, with nearly straight front; convexity regular; three pairs of moderately well-defined glabellar furrows
3) Fixed cheeks two-thirds width of glabella on midline
4) Fixed cheeks very slightly upsloping
5) Posterior limbs same length as occipital ring
6) A brim, a marginal furrow, a border

Remarks.—*Proveedoria* shows the closest relationship to the genus *Kochiella*, which was originally described from beds assigned to the Lower Cambrian in Greenland, but also appears to be represented in the *Ptarmigania* fauna of early Middle Cambrian age. However, the type species differs in too many features to be easily included in *Kochiella*. The following points are to be noted: a) in *Kochiella* the eyes are relatively somewhat smaller in proportion to the rest of the cranidium than they are in *Proveedoria;* b) the glabella in *Kochiella* is more broadly conical, as wide at the base as its length; c) in *Kochiella* the palpebral lobes are definitely on the posterior one-third line of the glabella.

There is also a close relationship to the genus *Chancia* from the Spence shale, but from that genus *Proveedoria* differs in a) the glabella is definitely more tapered and elongate, and b) the palpebral lobes and eyes are proportionately longer.

PROVEEDORIA STARQUISTAE
Lochman, n. sp.
Plate 70, figures 7–14

Cranidium subquadrate, average specimen 5 mm. across the eyes by 4½ mm. in length; glabella tapered conical, longer than wide with front nearly straight across, convexity low, regular with a faint median ridge; three pairs of moderately deep glabellar furrows, first very short, slit-like, second longer, slightly curved, third still longer, arcuate; dorsal furrow narrow, well-defined; occipital furrow wide, deep at sides, shallow across center; occipital ring of medium width, subtriangular, flat; brim of medium width, flat, moderately downsloping, practically flat with a very shallow median groove; anterior margin evenly curved. Fixed cheeks two-thirds width of glabella, flat, slightly downsloping; palpebral lobes of medium size, situated almost on posterior one-third line of glabella; palpebral furrow narrow, faint; ocular ridge very narrow, faint, curving to anterior corners of glabella; posterior limbs narrow, same length as occipital ring, crossed by a narrow, well-defined marginal furrow. Free cheek short, narrow, with medium eye at inner angle; ocular platform of medium width, slightly convex, downsloping; marginal furrow narrow, shallow; border narrow, flat, horizontal, with a short pointed anterior projection and a short flat genal spine. Facial suture cutting anterior margin well out at sides, curving back to marginal furrow, then running diagonally in to and around palpebral lobes; thence running straight out before curving abruptly back to posterior margin within genal angle.

Thorax and pygidium not known.

Outer surface of test thickly covered with fine granules, passing into short imbricating ridges on border of cranidium and free cheek; inner surface not known.

Remarks.—This species is represented by seven cranidia and five free cheeks from one collection. The fauna from this bed is quite small, consisting of this species, one cranidium of *Albertella* and several cranidia referred to *Kochaspis*. The very fine grained limestone matrix makes cleaning difficult, and the bed seems to be only sparsely fossiliferous.

Formation and Locality.—Middle Cambrian, Los Arrojos formation, collection 801i.

Types.—Holotype and paratypes, cranidia and free cheeks are deposited in the U. S. National Museum.

Glossopleura-Kootenia Zone
ARELLANELLA Lochman, n. gen.

Cranidium subquadrate; glabella truncato-conical with broadly rounded front, convexity highest posteriorly, sloping to low in front; three pairs of glabellar furrows;

dorsal furrow present; occipital furrow present; occipital ring triangular; brim and border present, separated by a faint marginal furrow; anterior margin rounded. Fixed cheeks three-fifths width of glabella, downsloping; palpebral lobes small, on midline of glabella; palpebral furrow very narrow; posterior limbs of medium width, same length as occipital ring, crossed by a broad shallow marginal furrow. Free cheek of medium width, elongate, with small eye at inner angle; ocular platform of medium width, flat, downsloping; marginal furrow obsolete; border narrow, with a long pointed anterior projection and a genal spine (broken). Facial suture cutting anterior margin on line with dorsal furrow, curving out, then straight in to and around palpebral lobes, thence out and back to posterior margin within genal angle.

Thorax not known.

Pygidium narrowly transverse, nearly twice as wide as long; axis wide, slightly tapered, extending nearly full length of pygidium, divided by two faint furrows; pleural platforms about one-half width of axis, downsloping, divided by two faint interpleural grooves; no marginal furrow seen; very narrow border may be present.

Outer surface may be smooth (worn in all specimens); inner surface not known.

Genotype.—*Arellanella caborcana* Lochman, n. sp.

Generic Characters: Cranidium.—

1) Palpebral lobes small, on midline of glabella
2) Glabella very broadly conical, truncato-conical, as long as wide; convexity highest posteriorly, sloping to low anteriorly; three pairs of glabellar furrows
3) Fixed cheeks three-fifths width of glabella
4) Fixed cheeks slightly downsloping
5) Posterior limbs same length as occipital ring
6) A brim, a marginal furrow, a border

Remarks.—This genus is erected for two species recognized from one collection. The species are represented by a large number of cranidia and three pygidia, but most of them are smaller than the holotype of the type species. None of the specimens is too well preserved as they occur in a crumbly limestone so that the outer surface of the test is leached and the edges often broken. The species are associated with *Alokistocare* and *Kistocare tontoensis* (Resser).

Arellanella seems most closely related to *Pachyaspis* Resser, a member of the so-called *Ptarmigania* fauna which is a limestone faunal assemblage apparently equivalent in age to the lower part of the *Glossopleura-Kootenia* zone. However, these two species could not be placed in *Pachyaspis* as they differ consistently from that genus in the same diagnostic features of the cranidium, i.e.; a) the position of the palpebral lobes, b) the shape of the glabella, c) the width of the fixed cheeks, and d) the slope of the fixed cheeks.

ARELLANELLA CABORCANA Lochman, n. sp.
Plate 70, figures 22–26

Cranidium nearly square, very slightly wider than long; average specimen 8 mm. across eyes by 7 mm. in length; glabella broadly conical, with very broadly rounded front, convexity low; three pairs of glabellar furrows, well-defined on inner surface, faint on outer surface, in front of first pair on inner surface is an elongate slit at each side which may represent traces of another pair, first pair short, straight, second pair longer, slightly curved, third still longer, arcuate; dorsal furrow broad, shallow at sides, narrower and fainter across front; occipital furrow of medium width, deeper at sides, shallower across center; occipital ring of medium width, triangular (broken); brim of medium width, slightly convex, gently downsloping, merging smoothly into the narrow, flat, slightly upsloping border as marginal furrow is apparently obsolete; anterior margin evenly rounded. Fixed cheeks three-fifths width of glabella on midline, slightly convex, downsloping; palpebral lobes small, narrow, on midline of glabella; palpebral furrow narrow, faint; ocular ridge obsolete; posterior limb of medium width, same length as occipital ring, crossed by a broad, shallow marginal furrow. Free cheek of medium width, elongate, with small eye at inner angle; ocular platform of medium width, flat, gently downsloping; marginal furrow obsolete; border narrow, slightly convex, and downsloping with a long pointed anterior projection and a genal spine (broken). Facial suture cutting anterior margin on line with dorsal furrow, curving out to marginal furrow, then straight back to and around palpebral lobes; then running diagonally

outward and back to cut posterior margin within genal angle.

Thorax not known.

Pygidium narrowly transverse, twice as wide as long; axis wide, slightly convex, only slightly tapered to broadly rounded end reaching nearly to posterior margin, divided by two very faint furrows into two narrow segments and a terminal portion; pleural platforms about one-half width of axis, convex, downsloping, divided by two very faint interpleural grooves into two narrow segments; no marginal furrow seen; very narrow border apparently present.

Outer and inner surface of test may be smooth.

Remarks.—Five cranidia of varying sizes, a free cheek and three small pygidia are referred to this species. The holotype is the largest and best preserved cranidium, though a peeled and somewhat worn specimen. All the paratype cranidia are much smaller.

Formation and Locality.—Middle Cambrian, Los Arrojos formation, collection 800a

Types.—Holotype and paratypes, cranidia, pygidia and free cheek are deposited in the U. S. National Museum.

CABORCELLA Lochman, n. gen.

Cranidium short, transverse; glabella triangular with flat, curved front, strongly convex at sides and front; three pairs of glabellar furrows; dorsal furrow present; occipital furrow sinuous; occipital ring unknown; brim flat; marginal furrow broad with a low median rise; border upturned. Fixed cheeks three-fourths the width of glabella, steeply upsloping near furrow, then gently upsloping beyond; prominent, curved ocular ridge; palpebral lobes small, at or just back of midline of glabella; no palpebral furrow; posterior limbs nearly same length as occipital ring, width one-half the length, directed posteriorly at the ends. Free cheek not known. Facial suture cutting anterior margin on line with dorsal furrow, curving out, then straight back and around palpebral lobes; then running out and back to cut posterior margin close to genal angle.

Thorax and pygidium not known.

Outer surface of cranidium sparsely covered with large granules; inner surface not known.

Genotype.—*Caborcella arrojosensis* Lochman, n. sp.

Generic Characters: Cranidium.—

1) Palpebral lobes small, situated at or just back of midline of glabella
2) Glabella very broadly conical, broader than long so appears triangular, moderately convex, steep at sides and front; three pairs of short glabellar furrows
3) Fixed cheeks approximately three-fourths width of glabella on midline
4) Fixed cheeks elevated near dorsal furrow, then slightly upsloping
5) Posterior limbs triangular, ends directed backward, length slightly shorter than occipital ring
6) A brim; a marginal furrow with low median rise; a border

Remarks.—The genus is established for the Mexican species and one other species described as *Acrocephalites? trifossatus* Mason, 1935, from the Cadiz formation, Marble Mountains, California. The types of the latter have not been examined, but Mason's illustrations indicate the close relationship between the two species in spite of the poor preservation of his specimens.

Caborcella is considered most closely related to *Poulsenia*. *P. granosa* Resser from the Langston formation shows many features in common even to the shallow side pits in the marginal furrow. However, the cranidia of the two genera differ definitely in two distinct features: in *Poulsenia* a) the glabella is regularly conical, longer than wide and quite broadly rounded across the front, and b) the fixed cheeks are only regularly upsloping.

CABORCELLA ARROJOSENSIS Lochman, n. sp.
Plate 70, figures 19–21

Cranidium wider than long; glabella triangular with flatly curved front, base as wide as length, strongly convex with a steep slope to sides and in front; three moderately impressed glabellar furrows, first short, straight, second longer, diagonal, third still longer, arcuate; dorsal furrow broad, shallow; occipital furrow broad, sinuous, deep at sides; occipital ring broken; brim narrow, flat, steep in front of fixed cheeks, becoming nearly horizontal in front of glabella; marginal furrow narrow, shallow at sides, widen-

ing to a shallow pit on line with edge of glabella, then sloping up to center as a broad shallow furrow; border narrow, vertical, rounded on top, continuing down as a vertical doublure in front; anterior margin straight in center, curved slightly at sides. Fixed cheeks approximately three-fourths width of glabella, convex, sloping up to one-half height of glabella, then flattening; palpebral lobes small, situated just posterior to midline of glabella; prominent curved ocular ridge; palpebral furrow not seen; posterior limb triangular, width one-half the length, which is nearly same as occipital ring, directed backward at ends, crossed by a broad, shallow marginal furrow. Free cheek not known. Facial suture cutting anterior margin about half way out, curving out to marginal furrow, then running straight up and back to and around palpebral lobes; thence curving outward and finally backward abruptly to cut posterior margin just within genal angle.

Thorax and pygidium not known.

Outer surface of cranidium appears smooth except for a row of coarse granules on brim and a few granules on fixed cheek following dorsal furrow; inner surface apparently smooth.

Remarks.—This species is represented in the Mexican material by four cranidia from one locality. Except for the poor surface the preservation is fairly good. The peculiar structure of the marginal furrow with a shallow pit on each side just in front of the dorsal furrow, and then a rise upward of the surface of the furrow to the center could easily give the impression of an obscure or poorly developed median boss. It may actually be the inception of one, but this does not develop in the two known species into anything which could be considered a real boss.

Formation and Locality.—Middle Cambrian, Los Arrojos formation, collection 8C0c.

Types.—Holotype and paratypes, cranidia, are deposited in the U. S. National Museum.

KISTOCARE Lochman, n. sp.

Cranidium subquadrate; glabella broadly conical, very slightly longer than wide, with broadly rounded front, regularly convex; three pairs of well-defined glabellar furrows with a fourth pair occasionally suggested by a pair of frontal pits; dorsal furrow present; occipital furrow present; occipital ring of medium width; brim and border present, separated by a marginal furrow; anterior margin curved. Fixed cheeks very slightly over one-half width of glabella, slightly upsloping; palpebral lobes medium-sized, on posterior one-third line of glabella; palpebral furrow present; ocular ridge strongly curved; posterior limbs same length as occipital ring, crossed by a broad marginal furrow. Free cheek elongate, of medium width, with medium sized eye at inner angle; ocular platform of medium width, downsloping; marginal furrow present; border narrow with a short pointed anterior projection and a short slender genal spine. Facial suture cutting anterior margin well out at sides, curving out, back and into and around palpebral lobes, then diagonally out and back to cut posterior margin within genal angle.

Thorax not known.

Pygidium transverse; axis wide, strongly convex, extending to posterior margin, divided by two broad furrows; dorsal furrow obsolete; pleural platforms a little more than one-half width of axis, crossed by two or three faint interpleural grooves; no marginal furrow; no border distinguishable; the facet turns backward at a 45° angle so that the posterior and lateral margins form a continuous gentle curve.

Outer surface of test covered with fine granules; inner surface may be smooth.

Genotype.—*Kistocare corbini* Lochman, n. sp.

Generic Characters: Cranidium.—

1) Palpebral lobes medium-sized, situated on posterior one-third line of glabella
2) Glabella broadly conical, very slightly longer than wide; convexity regular; three pairs of well-defined glabellar furrows
3) Fixed cheeks slightly over one-half, but not two-thirds width of glabella
4) Fixed cheeks horizontal to very slightly upsloping
5) Posterior limbs same width as occipital ring
6) A brim, a marginal furrow, a border

Thorax not known.

Pygidium:

1) Transverse in outline; facet slants backward at 45° angle so that posterior and lateral margins are a continuous gentle curve

2) Axis wide; pleural platforms a little more than one-half width of axis
3) No marginal furrow; no border

Remarks.—This genus has been erected for the genotype and a second species which was originally described as "*Parehmania*" *tontoensis* Resser from the Grand Canyon region where it occurs in the same faunal assemblage as in the Mexican sections. These two species are known from a number of cranidia, a few free cheeks and one pygidium.

The genus appears most closely related to *Alokistocare* and can readily be placed in the family Alokistocaridae Resser. A comparison of the diagnostic generic characters of the two genera indicates the following differences: a) the palpebral lobes in *Kistocare* are definitely on the posterior one-third line of the glabella, not just back of the midline as in *Alokistocare;* b) the glabella has regular convexity in *Kistocare*, while in *Alokistocare* it is highest posteriorly sloping downward anteriorly; c) in *Kistocare* the fixed cheeks are just over one-half the width of the glabella whereas in *Alokistocare* they are well over one-half and nearly two-thirds the width of the glabella, and d) there is no trace of a median bulge on brim, border or marginal furrow in *Kistocare.*

KISTOCARE CORBINI Lochman, n. sp.
Plate 70, figures 1–6

Cranidium subquadrate, largest specimen 8 mm. across the eyes by 7 mm. in length; glabella conical, slightly longer than wide, broadly rounded in front, convexity low, regular; three pairs of moderately deep glabellar furrows, first pair short, diagonal forward, second pair short, straight, third longer, arcuate; dorsal furrow narrow, deep at sides, shallow across front; occipital furrow narrow, deep at sides, broad and very shallow across center; occipital ring of medium width, slightly convex, with a small median node; brim and border nearly subequal, brim just a bit narrower, flat, downsloping; marginal furrow narrow, shallow, becoming quite faint on median line; border narrow, flat, nearly horizontal (very slight downslope can be seen); anterior margin evenly curved. Fixed cheeks slightly over one-half width of glabella, slightly convex, very slightly upsloping; palpebral lobes wide, raised, medium-size, on posterior one-third line of glabella; palpebral furrow broad, shallow; ocular ridge wide, prominent, strongly curved; posterior limbs narrow, same length as occipital ring, crossed by a broad, well-defined marginal furrow. Free cheek narrow, elongate, with medium-sized eye at inner angle; ocular platform of medium width, one and one-half times the border, flat, gently downsloping; marginal furrow narrow, shallow; border narrow, very slightly convex, almost horizontal, with a slender pointed anterior projection and a short slender genal spine. Facial suture cutting anterior margin far out at sides, curving out to marginal furrow, then curving back and in to and around palpebral lobes; thence running diagonally outward and curving abruptly back to cut posterior margin within genal angle.

Thorax not known.

Pygidium broadly transverse; axis wide, strongly convex, very slightly tapered to a broadly rounded end, apparently extending to posterior margin, divided by two broad faint furrows into two narrow segments and a long terminal portion; dorsal furrow obsolete; pleural platforms slightly more than one-half width of axis, flat, then steeply downsloping, two very faint narrow interpleural grooves; marginal furrow obsolete; no border distinguishable; a long, narrow facet turns abruptly back at a 45° angle so that the lateral and posterior margins form a single gentle curve.

Outer surface of test thickly covered with fine granules; inner surface apparently smooth.

Remarks.—This species is represented by a number of cranidia, a few free cheeks and a pygidium from two collections. The best preserved specimens are unfortunately the smaller cranidia so that the holotype and best paratypes are only about 3 mm. in length. The larger cranidia are too broken and crushed to represent the species well.

This species differs from *Kistocare tontoensis* (Resser) in the somewhat wider proportion of the brim to the border, and the nearly horizontal position of the border.

Formation and Locality.—Middle Cambrian, Los Arrojos formation, collections 800c, 801n.

Types.—Holotype and paratypes, crani-

dia, pygidium and free cheeks are deposited at the U. S. National Museum.

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TWO NEW EURYPTERIDS FROM THE SILURIAN OF INDIANA

ERIK N. KJELLESVIG-WAERING

ABSTRACT—The eurypterid fauna of the Kokomo waterlime of Indiana is here reviewed, and *Onychopterus* is considered a distinct genus from *Eurypterus*, whereas *Eurypterus ranilarva* is found to be synonymous with *O. kokomoensis*. The first known representative in this fauna of the genus *Pterygotus*, and an unusual *Onychopterus* are described. Lists of the known representatives of *Pterygotus* and *Onychopterus* in North America are included.

THE well known eurypterid fauna of the Kokomo waterlime at Kokomo, Indiana, was first described by Claypole in 1890. From specimens collected by C. E. Newlin he erected the genus *Eurysoma*, describing *E. newlini*, and noted that part of the specimens "so far as could be determined by a hasty examination belong to the species *Eurypterus lacustris*." (Claypole 1890a, p. 259.) Inasmuch as *Eurysoma* was preoccupied, he substituted the name *Carcinosoma* later the same year (1890b). In 1894 he described another species *C. ingens*, believing that the outlines of the appendages and greater size separated it from *C. newlini*. Miller and Gurley (1896) described *Eurypterus kokomoensis*, and Clarke and Ruedemann (1912) published the results of their studies in a classic monograph. After exposing the distal end of the "swimming leg" of *E. kokomoensis*, they erected a new subgenus, *Onychopterus* for this species. The *Eurypterus ranilarva* and the only American representative of the Scottish genus *Drepanopterus*, naming their species *D. longicaudatus*. *Carcinosoma* was considered a synonym of *Eusarcus*, and Claypole's *C. ingens* was relegated to the synonymy of *E. newlini*. They noted that Claypole's hasty identification of *Eurypterus lacustris* was very likely erroneous and this form probably should be identified as *E. ranilarva*.

Størmer in 1934 noted that the name *Eusarcus* had been previously used, and therefore reinstated Claypole's *Carcinosoma*.

The Kokomo fauna, as previously known, consists of the following forms:

Drepanopterus longicaudatus Clarke and Ruedemann
Carcinosoma newlini (Claypole)
Eurypterus ranilarva Clarke and Ruedemann
E. (*Onychopterus*) *kokomoensis* Miller and Gurley

The types of *Eurypterus ranilarva* and *E.* (*Onychopterus*) *kokomoensis* have been restudied by the writer, who has reached a different conclusion from that of Clarke and Ruedemann.

The original description of the genus *Onychopterus* is as follows:

> This subgenus is proposed for *Eurypterus kokomoensis* to give expression to the phylogenetic importance of the species as indicating the path of development of *Dolichopterus*, *Drepanopterus* and *Stylonurus* from *Eurypterus*. Its distinctive characters are the large squarish carapace, the lack of differentiation of the fourth pair of endognathites, the spur-like form of the ninth segment of the swimming legs and the styliform telson. (Clarke and Ruedemann, 1912, p. 212.)

It is apparent that Clarke and Ruedemann referred *E. ranilarva* to *Eurypterus* rather than to the subgenus *Onychopterus* because they believed it to lack the typical spurlike claw, or ninth segment, of the "swimming," or sixth, appendage. Of the three described specimens of this species (University of Chicago Walker Museum 12905, 12906, 12907) only 12905 (the holotype) has the distal end of the sixth appendage preserved on the right side. This is not preserved on the left sixth appendage of the holotype nor on the two paratypes. The right appendage of the holotype clearly shows the characteristic claw of *Onychopterus* and therefore this species is referable to that subgenus.

The principal difference between *E. ranilarva* and *E.* (*Onychopterus*) *kokomoensis* cited by Clarke and Ruedemann is the greater width of the carapace in the former. These authors have noted that such a difference may be sexual (1912, p. 211).

Størmer (1933, p. 77) also states that perhaps these forms are conspecific. The carapaces of *E. ranilarva* differ in ratio of length to width from 6.9:10 to 7.1:10 whereas those of *O. kokomoensis* range from 8.1:10 to 8.4:10. Perhaps this difference is due to preservation (all specimens measured are completely flattened) and is not significant. Carapaces of *Eurypterus microphthalmus* measured by Clarke and Ruedemann (1912, pp. 193–194) differ in proportions from 6.4:10 to 7.5:10 whereas a glance at the compressed carapaces of *Eurypterus* (*Hughmilleria?*) *maria* in figure 37 of their monograph shows that the wide differences in the proportion of length to width of carapace are not unusual within a single species and are likely to result from differences of preservation. Therefore the difference in the proportions of *E. ranilarva* and *O. kokomoensis* is neither unique nor unusual and is not a valid criterion for the differentiation of species represented by compressed specimens. Inasmuch as these two forms are similar in all other respects it is the writer's conclusion that they are specifically identical. Furthermore, it is the writer's opinion that the lack of differentiation of the fifth appendage, and the presence of the spur-like claw of the sixth appendage is adequate basis for considering *Onychopterus* to be a genus separate and distinct from *Eurypterus*, rather than a subgenus.

The main purpose of this paper is the description of two interesting additions to the Kokomo fauna. The first is a robust eurypterid which represents the first *Pterygotus* known from this fauna and differs in many respects from the common Bertie waterlime species of this genus. The other is an unusual, stout eurypterid which has been refered to the genus *Onychopterus*. It exhibits the same lack of differentiation of the fifth appendage but differs from previously known specimens of that genus in having very short, stout sixth appendages rather than the slender "swimming legs." This specimen is uncompressed and it is one of the few eurypterids known whose cephalic shield is wider than its abdomen. The proportions of the carapace are 5.3:10, which equals the great width of the widest known carapace of *E. dekayi* and surpasses the proportional width of *E. pustulosus*.

With these additions and changes the Kokomo eurypterid fauna consists of the following species:

Pterygotus ventricosus Kjellesvig-Waering, n. sp.
Drepanopterus longicaudatus Clarke and Ruedemann
Carcinosoma newlini (Claypole)
Onychopterus kokomoensis (Miller and Gurley)
Onychopterus limuloides Kjellesvig-Wearing, n. sp.

The writer is particularly indebted to Dr. G. Arthur Cooper of the U. S. National museum who kindly made available the two specimens herein described. He further wishes to acknowledge and thank R. V. Hollingsworth of the Paleontological Laboratory, Midland, Texas, for his assistance and comments during the preparation of this paper. He is also indebted to D. S. Holdcroft, of Tulsa, Oklahoma, who kindly contributed the photographs of both specimens.

Class MEROSTOMATA (Dana) Woodward
Order EURYPTERIDA Burmeister
Family PTERYGOTIDAE Clarke and Ruedemann
Genus PTERYGOTUS Agassiz
PTERYGOTUS (PTERYGOTUS) VENTRICOSUS Kjellesvig-Waering n. sp.

This species, the first *Pterygotus* known from the Kokomo waterlime, is represented by a single individual preserved as a dorsal impression. It is nearly complete except for parts of the appendages and the distal end of the broad telson. Although preserved as a flattened impression on light gray, finely-crystalline, dolomitic limestone, the mesosoma exhibits slight relief. Patches of integument are dark brown in color, with a slight luster, and are apparently the remains of the original chitin preserved exactly as in some of the specimens of *Eurypterus fischeri*, and other forms, from the well known localities of Oesel. These patches can be easily lifted off the impression, and as a consequence most of the original integument has been lost. In plate 71, figure 1, the dark areas represent this original integument which as enlarged are shown in plate 71, figure 2. The entire specimen with the telson restored, indicates an individual approximately 290 mm. long.

Prosoma.—The carapace has been flattened, but it is clear that it was originally subquadrate in general outline, less than ⅓ wider than long. The anterior margins are broadly rounded; the posterior margin is truncated. The lateral margins probably were originally nearly parallel, although they may have been slightly rounded and reached their greatest divergence about the middle of the carapace.

Part of the outline of the right eye is barely visible at the anterior angle, and, although incomplete, appears to have been large, approximately, ⅔ of the length of the carapace. Facetta of the lateral eyes have not been preserved except that the area enclosed by the faint impression of the right eye exhibits integument of finer grain which undoubtedly covered the visual area. Ocelli are not apparent.

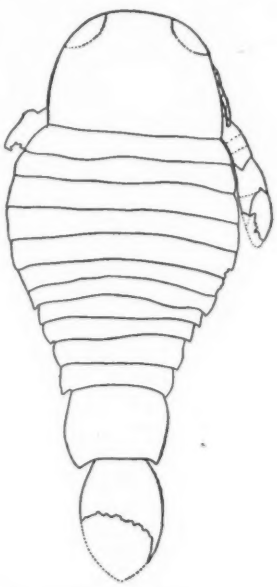

FIG. 1.—Outline of *Pterygotus ventricosus* Kjellesvig-Waering n. sp.

The carapace is marked throughout the central and posterior parts with coarse, semicircular scale-like impressions. Scales, similar in outline, but considerably smaller covered at least parts of the edges of the carapace. Insufficient patches of integument remain to reconstruct of this pattern.

Measurements.—

Prosoma:	
Length:	63.0 mm.
Width at base:	90.0 mm.
Compound eye:	
Estimated length:	24.5 mm.
Estimated width:	9.6 mm.

The appendages are poorly preserved as fragments. The right "swimming leg," or sixth appendage is almost completely preserved although most of the fourth to sixth segments are not sufficiently defined to permit description. The seventh and eighth segments, constituting the "paddle," are preserved only in part. The triangular lobe is unusually elongated, and although incomplete, the parts preserved indicate that this structure was considerably longer than wide. The outline of the entire sixth appendage however is typical of the genus. (See Text Figure 1.)

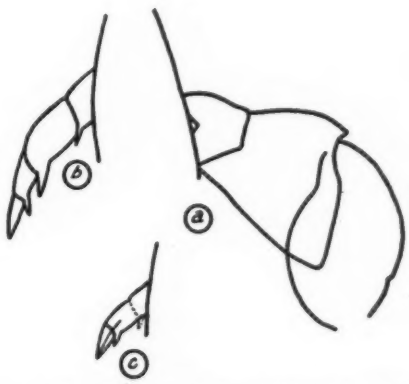

FIG. 2.—Appendages of *Onychopterus limuloides* Kjellesvig-Waering n. sp.

Two of the simple unspecialized walking legs are visible in part on the right side of the carapace. As in other species of the genus, these legs are without spines and very slender as compared to the rest of the body. These are probably the third and fourth appendages.

Mesosoma.—The mesosoma is ventricose in general outline, robust and stoutly constructed. The greatest width occurs at the fourth tergite which is approximately one fourth wider than the carapace. The mesosoma tapers into the metasoma without any

apparent sharp constriction. The first tergite greatly expands posteriorly to reveal the apparent gibbosity of this species. The postlateral angles are not produced into backwardly directed spurs as are the tergites of the metasoma. In general, each tergite is a narrow band about eight to ten times wider than long.

Patches of integument reveal that the mesosoma was covered with large, broad semicircular scale-like markings. These scales are irregular in size, some being three to four times as large as adjacent ones. (See plate 7, fig. 2.) The pattern cannot be determined because of the irregularity of the patches of integument preserved.

Measurements.—

Tergite I:	
Width at anterior margin:	90.0 mm.
Width at posterior margin:	104.0 mm.
Length:	13.0 mm.
Tergite II:	
Greatest width:	112.0 mm.
Length:	13.2 mm.
Tergite III:	
Greatest width:	115.5 mm.
Length:	13.0 mm.
Tergite IV:	
Greatest width:	119.5 mm.
Length:	11.5 mm.
Tergite V:	
Greatest width:	114.5 mm.
Length:	13.7 mm.
Tergite VI:	
Greatest width:	111.0 mm.
Length:	10.0 mm.

Metasoma.—The metasoma, like the mesosoma, is broad, and gradually tapers into the broad telson. Each postlateral angle is produced into a posteriorly-directed spur. The twelfth tergite is very long, being several times longer than the preceeding one.

The telson is broadly rounded. It is incomplete but appears to have been about half as broad as long. The parts preserved show that it was flat and there is no indication of a longitudinal median ridge. It was probably very similar to the telson of *Pterygotus anglicus* Agassiz. Faint serrations are noticeable on its edges.

The ornamentation of the metasoma is like that of the mesosoma although the scales of the epimera are smaller and narrower than the wide semicircular scales covering most of the tergites.

Measurements.—

Tergite VII:	
Greatest width:	93.0 mm.
Length:	11.5 mm.
Tergite VIII:	
Greatest width:	82.0 mm.
Length:	11.3 mm.
Tergite IX:	
Greatest width:	72.5 mm.
Length:	11.0 mm.
Tergite X:	
Greatest width:	65.0 mm.
Length:	10.0 mm.
Tergite XI:	
Greatest width:	56.5 mm.
Length:	14.0 mm.
Tergite XII:	
Greatest width:	51.5 mm.
Length:	36.5 mm.
Telson:	
Width at base:	24.0 mm.
Greatest width:	42.0 mm.
Estimated length:	58.0 mm?

Horizon and locality.—Kokomo waterlime, Kokomo, Indiana.

Holotype.—No. 88,130, U. S. National Museum, Washington.

Remarks.—*Pterygotus ventricosus* does not resemble any of the known North American species of the genus, but in many respects it is similar to the British *P. anglicus* Agassiz. (The Kokomo fauna also includes *Drepanopterus*, which is unknown elsewhere in North America, but is represented by several species in Scotland.) *P. ventricosus*, however, is distinguished from *P. anglicus* by its greater gibbosity, its different carapace outline, the difference of its sixth appendage, and the greater proportional width of the anterior

EXPLANATION OF PLATE 71

FIGS. *1, 2*—*Pterygotus ventricosus* Kjellesvig-Waering, n. sp., Kokomo waterlime, Kokomo, Indiana. *1*, ×.35; *2*, scale-like ornamentation along first and second mesosomatic tergites. Dark areas represent original integument. ×3.5. (p. 466)

1

2

Kjellesvig-Waering, Silurian Eurypterids

Kjellesvig-Waering, Silurian Eurypterids

part and base of the telson to the twelfth tergite. It also differs considerably from the common North American Bertie waterlime *P. macrophthalmus* and *P. buffaloensis* which are much more slender.

Of the nineteen described North American species of *Pterygotus*, only seven can be safely referred to subgenera. Most of the named species, particularly those of the Ordovician, are known only from fragments, and doubts exist as to subgeneric, and even generic, identifications. No attempt has been made in the compilation of the following list to check the relative standing of all species. Considerable additional material and study are needed before their relations to each other and to European species can be determined. Of particular importance in classification is the structure of the opercula. As known at present, the following species occur in North America:

Pterygotus (*Pterygotus*) *atlanticus* Clarke and Ruedemann	Devonian	New Brunswick
Pterygotus (*Pterygotus*) *buffaloensis* Pohlman	Silurian	New York
Pterygotus canadensis Dawson	Silurian	Ontario
Pterygotus (*Pterygotus?*) *cobbi* Hall	Silurian	New York
Pterygotus (*Pterygotus*) *cobbi* Hall *juvenis* Clarke and Ruedemann	Silurian	New York
Pterygotus (*Pterygotus?*) *deepkillensis* Ruedemann	Ordovician	New York
Pterygotus elleri Ruedemann	Devonian	New York
Pterygotus (*Erettopterus*) *globiceps* Clarke and Ruedemann	Silurian	New York
Pterygotus (*Erettopterus*) *grandis* (Pohlman)	Silurian	New York
Pterygotus (*Pterygotus*) *macrophthalmus* Hall	Silurian	New York
Pterygotus (*Erettopterus?*) *monroensis* Sarle	Silurian	New York
Pterygotus montanensis Ruedemann	Devonian	Montana
Pterygotus? nasutus Clarke and Ruedemann	Ordovician	New York
Pterygotus normanskillensis Clarke and Ruedemann	Ordovician	New York
Pterygotus priscus Ruedemann	Ordovician	New York
Pterygotus prolificus Clarke and Ruedemann	Ordovician	New York
Pterygotus (*Pterygotus*) *ventricosus* Kjellesvig-Waering	Silurian	Indiana
Pterygotus? vernonensis Ruedemann	Silurian	New York
Pterygotus walcotti Ruedemann	Ordovician	New York

As indicated by Størmer (1934, p. 286), *P. inexpectans* from the Devonian of New York, should probably be referred to the genus *Grossopterus*.

Family EURYPTERIDAE Burmeister
Genus ONYCHOPTERUS Clarke and Ruedemann
ONYCHOPTERUS LIMULOIDES Kjellesvig-Waering, n. sp.

The holotype, and only known specimen, is remarkably preserved in buff colored, finely crystalline dolomite. Details of the dorsal part of the body are clearly outlined in pyritic and carbonaceous material which makes it appear as if the edges of the eurypterid had been drawn on the fine matrix with a black pencil. The specimen is uncrushed, measures about 200 mm. in total length, and is almost complete including parts of the appendages of each side. Part of the dorsal side of the prosoma has been removed revealing the mouth, the interior of the "swimming legs" and a faint impression of the metastoma. The lateral eyes and ocelli, however, are not preserved.

Prosoma.—The prosoma is unusually wide, truncated at the posterior margin and broadening anteriorly to its greatest width at midlength. The anterior angles are broadly rounded and the anterior margin is straight. The carapace, bounded by a flat rim, slopes gently toward the center and attains its greatest thickness slightly behind this point where it is estimated to have been 7 mm. thick although removal of part of the dorsal surface makes measurement impossible.

The wide flat rim is 2.4 mm. wide at the anterior margin but narrows to 1.5 mm. in the postlateral angles. A single row of raised elongated pustules outlines the inner margin of the rim and parallels the margins

EXPLANATION OF PLATE 72

FIGS. *1, 2*—*Onychopterus limuloides* Kjellesvig-Waering, n. sp., Kokomo waterlime, Kokomo, Indiana; holotype. *1*, sixth telopodite or "swimming leg," ×2.2. First to eighth segments in normal position; M = mouth. *2*, the holotype, natural size. (p. 469)

of the carapace. *Stylonurus arnoldi* (Ehlers)* exhibits an ornamented rim not greatly unlike this species. The edges of the prosoma are scalloped with a single row of indentations which may indicate the presence of coarse scales. (Pl. 72, fig. 1)

The mouth is located slightly behind the midlength of the carapace. Although not distinctly preserved, it appears to be elliptical with the greater axis directed longitudinally.

The eyes and ocelli are not preserved.

The carapace appears to have been at least partly covered with small semilunar scales, but inasmuch as only small patches of the integument are preserved, the pattern is very indistinct.

Measurements.—

Length:	36.0 mm.
Greatest width:	68.0 mm.
Width at base:	64.5 mm.

The fifth and sixth appendages are preserved on the right side of the carapace. The former has been displaced forward whereas the latter occupies its normal position. The fourth, fifth, and part of the sixth appendages are present, in their positions, on the left side of the carapace.

The most remarkable of the appendages are the sixth, or "swimming legs" which are short, stout, broad structures differing greatly from the long, slender corresponding appendages of *O. kokomoensis*. The right side of the specimen shows all eight segments, the first five from the interior, and the last three from the exterior (pl. 72, fig. 2). Evidently the "swimming legs" are in their normal position and have not been pushed under the cephalic shield. Also the shortness of the "swimming legs" is related to the shortness of the second to fifth segments, particularly the fourth and fifth. The incomplete sixth appendage on the left side occupies the same position as the well preserved right "swimming leg." Its first five segments are too incompletely preserved to be described but the position of each is clearly visible.

* This form, originally described as *Eurypterus arnoldi* is, in the writer's opinion, a *Stylonurus* as indicated by the type of lateral eyes and slender mesosoma. In general characteristics it is similar to the Norwegian Silurian *S. ruedemanni* Størmer.

The carapace covers the proximal part of the sixth segment of these appendages, whereas in common typical forms of the Eurypteridae, such as *Eurypterus remipes* and *E. lacustris*, the carapace does not cover segments beyond the fourth. In the contemporaneous *Onychopterus kokomoensis*, the lateral margins of the carapace likewise cover the long, slender fourth segment. Although the unusually wide carapace is mainly responsible for the overlap of the first five segments in *O. limuloides* it is also in part due to the actual shortness of the sixth leg. The total length of the "swimming leg," measured in a straight line, with the eighth segment in normal position, is about 70 mm. which is only slightly more than the width of the cephalic shield.

The "paddle" of the sixth leg is considerably broader in proportion than it is in other typical members of the genera *Onychopterus* or *Eurypterus* (See text fig. 2a). The seventh segment is wider than the distance through the middle of the longitudinal axis of this segment, a condition that is reversed in *Eurypterus remipes*. The eighth segment is two-thirds as wide as long. The distal end of the palette is not preserved, but judging from the outlines of the palette, this structure possibly was broad as in *Eurypterus* rather than a spur as in *Onychopterus*. No traces of the suture of the triangular lobe of the seventh segment are visible.

Patches of integument of the underside of the third and fourth segments clearly reveal semicircular scale-like ornamentation.

The fifth appendages, or fourth walking legs, are visible on both sides of the carapace; the left one is in normal position whereas the one on the right side has been displaced anteriorly. The edges of the carapace cover most of the sixth segment. In *Eurypterus remipes* and *Onychopterus kokomoensis* the fifth segments are covered by the carapace. The last three segments are preserved on each side, and are stout and without spines such as those occuring in typical species of *Eurypterus*. Each segment has a spur-like projection at its posterior distal angle (See text fig. 2b). The spur on the eighth segment is finely striated but those on the sixth and seventh segments are not preserved sufficiently well to show orna-

mentation. These legs taper gradually and end in short thick spines.

The fourth appendage, or third walking leg, is in normal position on the left side of the carapace. Although this limb is not well preserved except for the distal end, it appears that the sixth and seventh segments are present and that the carapace covers the anterior portion of the sixth segment (See text fig. 2c). This leg is approximately half as thick as the fourth walking leg. It is, however, similar to that leg, being stout, without spines but having a single short spur at the end of each segment, and gradually tapers to end in a thick spine. This spine has a deep striation running longitudinally along the central axis.

Measurements.—(All are greatest measurements):

VI Appendage	
Segment No. 6:	
Width:	8 mm.
Segment No. 7:	
Width:	15 mm.
Length:	
at posterior edge:	21.0 mm.
at anterior edge:	11.0 mm.
Segment No. 8:	
Width:	14.5 mm.
Length:	21.0 mm.
V Appendage	
Segment No. 6:	
Width:	5 mm.
Segment No. 7:	
Width:	5 mm.
Length:	8.3 mm.
Segment No. 8:	
Length:	4.5 mm.
Segment No. 9 (terminal spine):	
Length:	4.5 mm.
IV Appendage	
Segment No. 6:	
Width:	2.5 mm.
Segment No. 7:	
Width:	2.0 mm.
Length:	3.5 mm.
Segment No. 8 (terminal spine):	
Length:	4.0 mm.
Width at base:	2.0 mm.

The metastoma, preserved as a faint impression posterior to the mouth, is too poorly preserved to be described.

Mesosoma.—The mesosoma, preserved entirely, is contracted and considerably wider than long but at its greatest width it is not as wide as the carapace. The abdomen is short and stout and covers approximately the same area as the wide prosoma. Each tergite is represented by a narrow band approximately one tenth as long as wide, without any noticeable development of spurs on the epimera. The first tergite is not appreciably narrower than the following, a condition that may be due to the telescoping of parts of the succeeding tergites during molting. The anterior tergites increase in width posteriorly and the greatest width of the abdomen occurs at the posterior part of the tergite. The fourth, fifth, and sixth gradually taper posteriorly without any abrupt constriction, into the post-abdomen. No ornamentation is apparent.

The following measurements of length are approximate and have been taken mainly on the left side of each tergite. The measurements of width are through the middle of each tergite.

Measurements.—

Tergite I:	
Estimated width:	65.0 mm.
Length:	5.0 mm.
Tergite II:	
Width:	65.5 mm.
Length:	6.5 mm.
Tergite III:	
Width:	66.0 mm.
Length:	7.5 mm.
Tergite IV:	
Width:	61.6 mm.
Length:	6.5 mm.
Tergite V:	
Width:	56.0 mm.
Length:	6.5 mm.
Tergite VI:	
Width:	43.5 mm.
Length:	9.0 mm.

Metasoma.—The metasoma is contracted so that the second tergite (No. 8) is almost completely telescoped into the preceding (no. 7) segment. The segments of the metasoma gradually taper into the stout telson. The last three segments are broadly rounded at the epimera, having their greatest width slightly posterior to the middle of each tergite. The last (No. 12) tergite is particularly broadly rounded and recurved in-

wardly in a posterior direction. Patches of integument of very small size occur on the last tergite and reveal faint scale-like ornamentation.

The telson is remarkably stout and long. It gradually tapers posteriorly and ends abruptly in a sharp point. In proportion to the body it is very long, being roughly one-third the total length.

Tergite VII:	
Width:	34.5 mm.
Length:	5.0 mm.
Tergite VIII:	
	telescoped
Tergite IX:	
Width:	29.0 mm.
Length:	9.5 mm.
Tergite X:	
Width:	26.0 mm.
Length:	11.5 mm.
Tergite XI:	
Width:	24.5 mm.
Length:	13.2 mm.
Tergite XII:	
Width:	20.0 mm.
Length:	17.0 mm.
Telson:	
Length:	64.5 mm.
Width at base:	7.5 mm.

Horizon and locality.—Kokomo waterlime, Kokomo, Indiana.

Collection.—No. 88,129, U. S. National Museum, Washington, D. C.

Remarks—Onychopterus limuloides differs greatly from all other known eurypterids. The form which resembles it most closely is *O. kokomoensis* although the differences are numerous and considerable. Among these are the greater width in carapace of *O. limuloides*, whose proportion of length to width is 5.3:10 as compared to 6.9:10 in the widest known compressed carapace of *O. kokomoensis;* the ornamentation of *O. limuloides* (*O. kokomoensis* is not ornamented); the short, stout appendages of *O. limuloides* (those of *O. kokomoensis* are long and slender); important differences in the structures of the sixth appendages; the rounded, recurving twelfth tergite of *O. limuloides* (this is flaring in *O. kokomensis*); and the long stout telson of *O. limuloides* (that of *O. kokomoensis* is slender, shorter, and styliform). Because of its wide carapace *O. limuloides* superficially resembles *Eurypterus dekayi* of the Bertie waterlime of New York. The relative outlines of the species, however, are sufficient to distinguish them.

Only three species of the genus *Onychopterus* have been described, all from North America. *Eurypterus pumilus* Savage, from the lower part of the Essex (Edgewood) limestone in Kankakee County, Illinois, apparently a young specimen, undoubtedly belongs to this genus. The slender appendages, devoid of spines, the wide doublure of the carapace, and the styliform telson indicate a species that closely resembles *O. kokomoensis*. The three species are:

Onychopterus kokomoensis (Miller and Gurley)	Silurian	Indiana
Onychopterus pumilus (Savage)	Silurian	Illinois
Onychopterus limuloides Kjellesvig-Waering	Silurian	Indiana

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NOTE ON THE STRATIGRAPHIC DISTRIBUTION OF *LEPIDORBITOIDES*[1]

C. M. BRAMINE CAUDRI
Tropical Oil Company, Bogotá, Colombia

ABSTRACT—The genus *Lepidorbitoides* has been considered diagnostic of the Cretaceous. Recently, however, it has been found in several localities around the Caribbean in deposits of Tertiary age. The present paper briefly discusses these data and their reliability for conclusions about the vertical range of the genus.

A new genus, *Bontourina*, is proposed to replace the invalid name *Hexagonocyclina* for one of the accompanying forms in some of the faunas mentioned, and a new type species (*B. inflata* Caudri, n. sp.) is chosen.

As an appendix, the question of the age of the Guaduas formation in Colombia is briefly discussed.

THE systematic position of Silvestri's genus *Lepidorbitoides* (including *Orbitocyclina* Vaughan) has been a matter of controversy for some time. The difficulty which presents itself here is that the morphologic difference between species of this genus and those belonging to *Lepidocyclina s. l.* is so slight that it is hardly possible to formulate a diagnosis. Nevertheless, the attempts to place *Lepidorbitoides* in the synonymy of *Lepidocyclina* have been few (Galloway) and have never been generally accepted, chiefly for stratigraphic reasons: *Lepidorbitoides* was considered to be restricted to the Upper Cretaceous, whereas *Lepidocyclina* is typical of the Tertiary (Middle Eocene to Miocene).

Reluctance to disturb the apparently well-established vertical distribution of these genera has in the past led to curious consequences. One species (*Lepidorbitoides tibetica* Douv. = *Polylepidina punjabensis* Davies), for instance, has been shifted four times from one genus to the other as the result of repeated changes in the age determination of its localities and of the weighting of stratigraphic versus morphologic evidence. It was first described by H. Douvillé (1916) as a *Lepidorbitoides*, from beds considered to be Tertiary in the field but determined to Danian on paleontological evidence (absence of *Nummulites* and presence of *Siderolites* and *Lepidorbitoides*). In 1937, L. M. Davies found similar forms in India, in the Paleocene Ranikot beds at Thal and in the Punjab Salt Range. He restudied Douvillé's Tibetan collection and found that it carried a typical Ranikot fauna, the *Siderolites* actually being *Miscellanea* and *L. tibetica* being "not really referable to *Lepidorbitoides* but to an Eocene subgenus of *Lepidocyclina*" (Davies 1937, p. 69). He combined the Tibetan and Indian specimens under the name of *Polylepidina punjabensis* n. sp.[2] In 1939, Tan Sin Hok, who was searching for phylogenetic lines in nepionic development rather than for rigid index fossils, placed these forms in *Orbitocyclina*, a subgenus of *Lepidorbitoides*. Rutten desired to preserve both genera because of their different lines of descent and also "for historical reasons" (1941, p. 37) and again referred these Tertiary forms to *Polylepidina*. Brönnimann (1944, p. 38, 40), relying on de Cizancourt's observations, shifted them for morphological reasons back to *Lepidorbitoides* (subgenus *Orbitocyclinoides*).

Similar disagreement has occurred regarding specimens from the Caribbean region. Caudri (1944) identified the small lepidocyclinoid orbitoid from the Paleocene of San Juan de los Morros, Venezuela, on morphological grounds as a *Lepidorbitoides* (*L. cf. planasi* Rutten), but Vaughan described and figured the same form from the Paleocene of Barbados as a *Polylepidina* (*P.*

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[2] Without examining the actual specimens it is difficult to judge whether the two species, *L. tibetica* and *P. punjabensis*, are really identical. Their illustrations suggest a notable difference in the shape of the equatorial chambers (compare also Tan's description with Davies'). If they are identical, the correct name would have been *Polylepidina tibetica* (Douv.).

barbadensis n. sp.) notwithstanding his own observation that "this species does not closely resemble any other known species of *Lepidocyclina*" (Vaughan 1945, p. 50).

As data on the occurrence of such small lepidocyclinoid orbitoids in beds intermediate between Upper Cretaceous and those in which true *Lepidocyclina* first appears have lately become more abundant, confusion will increase unless we determine the facts and reach a conclusion that is sound from a theoretical standpoint.

The facts are the following: the genus *Lepidocyclina s. l.* (comprising the subgenera *Polylepidina*, *Isorbitoina*,[3] *Pliolepidina*,[3] *Lepidocyclina s. s.*, *Nephrolepidina* (including *Trybliolepidina*), *Eulepidina* and *Multilepidina*) is known to appear in the Middle Eocene[4] and to die out in the Middle Miocene. In different regions (America, Central Europe, Morocco and Southern Europe, India, the Indopacific Region) the range of the genus as a whole varies within these boundaries and likewise the first and last occurrences of the subgenera are variable. However, the forms most frequently reported from the Middle Eocene (America, Morocco),[5] are *Polylepidina* and *Isorbitoina* and they really seem to be the most primitive subgenera in several respects. In America (Mexico) an antecedent line of descent can be traced for these forms, via *Eulinderina* and *Helicostegina*, originating from *Amphistegina lopeztrigoi* Palmer, all from the Middle Eocene (Barker & Grimsdale 1936). In other regions no such ancestral forms have as yet been recognized.

Lepidorbitoides s. l. (nowadays divided into the subgenera *Lepidorbitoides s. s.*, *Orbitocyclina*, *Asterorbis*, *Cryptasterorbis* and *Orbitocyclinoides*) was created in 1907 by Silvestri as a genus to include "tutte le antiche *Orbitoides* lepidocycliniformi del cretaceo superiore" (all the lepidocyclinoid forms from the Upper Cretaceous that were formerly included in *Orbitoides;* see Silvestri 1927) and was based on European material (types: *L. minor* Schlumb. and *L. socialis* (Leym.)).[5] The description mentions that the equatorial chambers communicate through minute pores instead of through stolons. Subsequently, similar forms were found in the Cretaceous of the New World, first by Douvillé (1927) and by Galloway (1928) who assigned them respectively to *Lepidorbitoides* and to *Polylepidina*, and later by Vaughan (1929) who discovered that they obviously possessed stolons and therefore should be distinguished as a new genus: *Orbitocyclina*. M. G. Rutten (1935a) restudied type material of the European *Lepidorbitoides*. He found that it does possess stolons and placed *Orbitocyclina* in the synonymy of *Lepidorbitoides*. Tan (1939) however, concentrating his studies on the nepionic development of these forms, reestablished *Orbitocyclina* as a separate genus because its nepiont is biserial (or quadriserial, in the case of some specimens of *Lepidorbitoides punjabensis* Davies, a species which according to Brönnimann probably belongs to his slightly different "subgenus" *Orbitocyclinoides*) and does not develop ad-auxiliary chambers, whereas *Lepidorbitoides s. s.* is always quadriserial and possesses, in addition to the two primary auxiliary chambers, a number of ad-auxiliary chambers. Rutten (1940) contested the observations about the presence of ad-auxiliary chambers (in the present author's opinion not quite convincing), but in 1941 concluded that *Orbitocyclina* deserves recognition as a subgenus differing from *Lepidorbitoides s. s.* in nepionic development. Rutten did not doubt the strictly Cretaceous age of *Lepidorbitoides s. l.*[6] and referred *L. tibetica-punjabensis*, which shows both types of nepionic pattern, to *Polylepidina*. No one has been able to trace the origin of *Lepidorbitoides* in a satisfactory way, because of its earlier appearance in the Cretaceous and because it is, especially in its vertical section, less

[3] The correct nomenclature of these subgenera is open to argument but they are meant here to include forms without concentric stolons between the equatorial chambers, either with a bilocular (*Isorbitoina*) or multilocular (*Pliolepidina*) nucleoconch.

[4] Ignoring for the moment the Paleocene "*Polylepidina*" *punjabensis* and "*Polylepidina*" *barbadensis*.

[5] The Moroccan *L. mauretanica* Bourc. & David, which was found in combination with a *Nephrolepidina* (see Senn 1935, p. 87), seems to be an *Isorbitoina*.

[6] The type locality of his *L. planasi* (1935b, p. 537) is erroneously given as Upper Eocene (p. 528) of the same paper).

primitive than the early *Polylepidinas* and *Isorbitoinas* from the Middle Eocene, it seems obvious that the two genera must represent parallel evolutionary lines which developed independently into the same morphologic pattern in different periods of stratigraphic history.

A new difficulty is introduced by the increasingly frequent discovery of small *Lepidocyclina*-like orbitoids in the lower part of the Tertiary that do not fit into Barker and Grimsdale's scheme of the evolution of *Lepidocyclina*. Referring them to the subgenus *Polylepidina* as Davies and Vaughan have done can not solve this problem but only shifts it. The conclusion that they really belong to *Lepidorbitoides* and that this genus (subgenus *Orbitocyclina*, including perhaps *Orbitocyclinoides*) crosses the Cretaceous-Tertiary boundary seems to offer a simpler solution. Against this the following objections might be raised:

1. This would be very exceptional because practically no genus of "larger" Foraminifera is certainly known to continue across that boundary,
2. The age of the localities from which these forms have been reported may have been misdetermined and may be Cretaceous rather than Tertiary,
3. These forms may be reworked Cretaceous fossils deposited in Tertiary strata, where they are associated with typical Tertiary faunas.

The first objection is a valid one. If *Lepidorbitoides* really crosses this boundary, it is about the only genus to do so, as far as present knowledge goes.[7]

The second one can be dismissed as may be clearly seen from the following faunal lists for the Caribbean Region in which, besides the available published data, some of the present author's own observations are entered and which include such established Paleocene and Eocene localities as the Soldado Rock off Trinidad (Kugler 1938) and the Scotland Formation of Barbados (Senn 1940).

The possible reworking of the specimens of *Lepidorbitoides* in the Caribbean Tertiary can not as yet be satisfactorily evaluated.

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[7] The belief that *Nummulites* and *Discocyclina* occur in the European Cretaceous is apparently ineradicable. In most cases, however, the age determinations of their localities is debatable (see Caudri 1937, p. 410–412).

In the Caribbean region only *Ranikothalia* and *Borelis*, apart from *Lepidorbitoides*, are reported to continue from the Cretaceous into the Tertiary (Caudri 1944, distribution chart), but these data are not reliable.

The occurrence of *Ranikothalia* (*Operculina bermudezi*) in the Maestrichtian of Cuba was published by Palmer (1934), but later Mrs. Palmer changed her opinion on the age of the beds in which the species was found. In a personal letter, dated March 26, 1945, she stated: "It was most unfortunate that we used the locality we did for collecting the cotypes of *Operculina bermudezi*, for it is now quite clear that the matrix—with *O. bermudezi*—is Eocene and that there were chunks of Cretaceous shale in the outcrop, either in a conglomerate or possibly accidentally due to bridge embankment construction. In due course I hope to write a correction of the age reference with a list of the associated species in a non-conglomeratic bed. That, I fear, will upset the nomenclature again for *O. bermudezi* has priority over (*Ranikothalia*) *tobleri* but the age determination of *O. bermudezi* must certainly be corrected."

Mrs. Palmer's much regretted death prevented the publication of her findings, but it is certainly in agreement with her conscientious and generous mind to make them known and allow me to use them. I can add that in type material which Mrs. Palmer sent me from Cuba (coll. No. 2093) I have found *Ranikothalia bermudezi* (flat typical forms and thick lenticular forms) in a curiously mixed fauna, associated with *Discocyclina grimsdalei* Vaughan and Cole, *Discocyclina aguerreverei* Caudri, *Discocyclina* (*Discocyclina*) sp., *Vaughanina*, *Orbitocyclina* and *Asterorbis*. The question whether *R. bermudezi* is identical with *R. tobleri* or any other species of *Ranikothalia* needs further study.

The Cretaceous "*Borelis*" recorded in the same chart is *Borelis cardenasensis* Barker & Grimsdale (1937). This is a small globular form from the highest beds in the Mexican Cretaceous, overlying the typical Maestrichtian which carries *Lepidorbitoides* (*Orbitocyclina*) *minima* Douv. and *Meandropsina ? rutteni* Palmer. It is distinguished from Tertiary species of *Borelis* by far more pronounced subdivision of the chamberlets into more than one layer, and the authors themselves state (pp. 175–176) that it shows relationship to Reichel's Cretaceous genus *Praealveolina*. Although they do not want to make a direct connection between their Mexican species and that Old World genus, they admit that *B. cardenasensis* might represent the same primitive stage of development, and they refer it to *Borelis* only to avoid the creation of a new genus on inadequate grounds. At the time they wrote, Reichel's Monograph of the Alveolinidae (1936–1937) had not yet appeared in full, but it seems worth while now to restudy "*Borelis*" *cardenasensis* with the help of Reichel's lucid new systematics.

Reworking has certainly played an important role in this region and the sediments and specimens at some of the localities mentioned below look somewhat suspicious (for instance, the remarkable mixed silty-and-gritty deposits of the Murphys beds in Barbados and the fauna from Biche, Trinidad). At numerous places in Trinidad, however, where reworking undoubtedly has occurred it can usually (as far as "larger" Foraminifera are concerned) be traced back clearly to the Paleocene (Soldado Rock, Point Bontour, Lizard Springs Area) but not with anything like probability to the Cretaceous. Nevertheless, the possibility that the specimens of *Lepidorbitoides* were derived from older strata must be kept in mind.

Faunas from Tertiary Localities in the Caribbean Region which Include Lepidorbitoides

I. Barbados

1. Paleocene blocks in Upper Eocene Joes River mudflows

S. 45 (see Vaughan 1945)
Ranikothalia antillea (Hanz.)
Ranikothalia soldadensis (Vaughan and Cole)
Ranikothalia ? sp.
Discocyclina barkeri Vaughan and Cole
Discocyclina grimsdalei Vaughan and Cole
Lepidorbitoides cf. planasi Rutten (=*Polylepidina barbadensis* Vaughan)

S. 95 (see Vaughan 1945)
Ranikothalia antillea (Hanz.)
Ranikothalia soldadensis (Vaughan and Cole)
Ranikothalia sp.
Discocyclina barkeri Vaughan and Cole
Discocyclina grimsdalei Vaughan and Cole
Discocyclina mestieri Vaughan
Lepidorbitoides cf. planasi Rutten

S. 96 (see Vaughan 1945)
Ranikothalia antillea (Hanz.)
Ranikothalia soldadensis (Vaughan and Cole)
Discocyclina barkeri Vaughan and Cole
Discocyclina mestieri Vaughan
Lepidorbitoides cf. planasi Rutten

S. 97 (see Vaughan 1945)
Discocyclina grimsdalei Vaughan and Cole
Lepidorbitoides cf. planasi ? (Vaughan's figure, pl. 19, fig. 5) (this form seems to differ from the other figured specimens in the shape of its equatorial chambers)

Explanation of Plate 73

Figs. *1, 2, 9, 11*—*Lepidorbitoides* cf. *planasi* M. G. Rutten ×47. *1*, collected by the writer from the Walkers beds (Lower Eocene) Barbados, at Senn's locality S. 587; *2*, same, ×47, from the Velle Hondo formation, Paleocene or Lower Eocene, Trujillo, Venezuela; *9*, same, ×42, a reworked specimen derived from the Paleocene, found in the Mount Moriah silt (Upper Eocene) at Point Bontour, Trinidad; *11*, same, ×59, from the Paleocene limestone near San Juan de los Morros, Guárico, Venezuela. (p. 479)

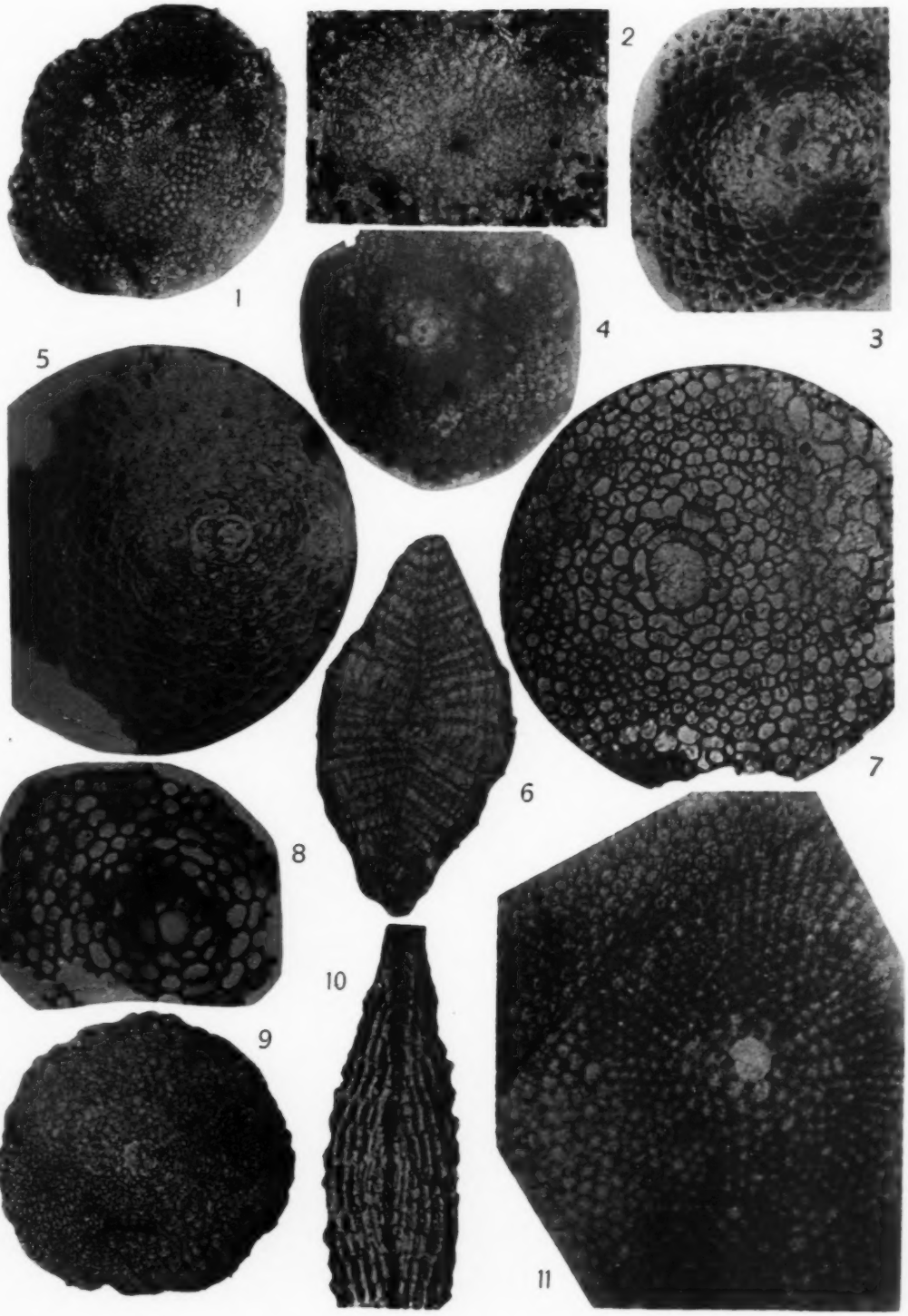
3, 5, 10—*Polylepidina* cf. *vichayalensis* L. Rutten, ×42, from the Mount Moriah silt (Jackson, Upper Eocene), Point Bontour, Trinidad. (p. 479)

4—*Lepidorbitoides* sp., ×47, collected by the writer from the Walkers beds (Lower Eocene), Barbadoes, at Senn's locality S. 587. (p. 477)

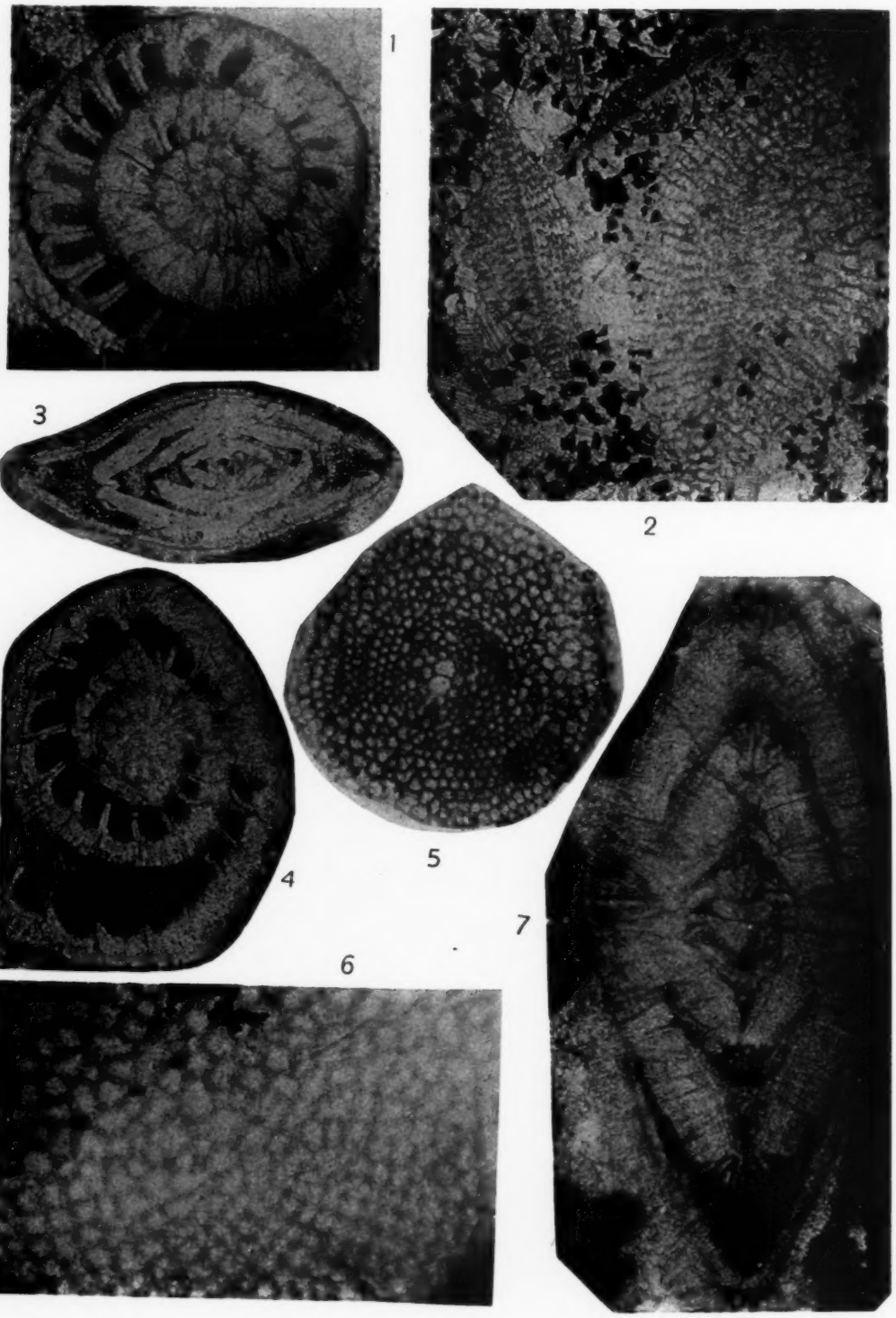
6—*Bontourina inflata* Caudri n. gen., n. sp., ×42, vertical section of a reworked specimen derived from the Paleocene, in the Mount Moriah silt (Upper Eocene), Point Bontour, Trinidad. (p. 477)

7—*Polylepidina proteiformis* Vaughan, ×42, from the Mount Moriah silt (Jackson, Upper Eocene), Point Bontour, Trinidad. (p. 479)

8—*Polylepidina* aff. *chiapasensis* Vaughan ×42, from the Mount Moriah silt (Jackson, Upper Eocene), Point Bontour, Trinidad. (p. 479)



Caudri, Tertiary Foraminifera



Caudri, Tertiary Foraminifera

S. 368 (see Vaughan 1945)
Discocyclina barkeri Vaughan and Cole
Discocyclina grimsdalei Vaughan and Cole
Athecocyclina soldadensis Vaughan and Cole var. *calebardensis* Vaughan
Lepidorbitoides cf. planasi Rutten

Material examined by the author (from S. 368 and other localities)
Ranikothalia antillea (Hanz.)
Ranikothalia tobleri (Vaughan and Cole)
Discocyclina aguerreverei Caudri
Athecocyclina soldadensis Vaughan and Cole var. *calebardensis* Vaughan
Bontourina[8] sp. (cf. *meandrica* (Caudri))
Lepidorbitoides cf. *planasi* Rutten

2. Walkers member of the Lower Scotland Formation (Lower Eocene)

S. 587 (material collected by the author)
Ranikothalia cf. antillea (Hanz.)
Discocyclina cf. grimsdalei Vaughan and Cole
Discocyclina cf. bullbrooki Vaughan and Cole
Athecocyclina sp.
Lepidorbitoides cf. planasi Rutten (Pl. 73, fig. 1)
Lepidorbitoides sp. (with arcuate equatorial chambers) (Pl. 73, fig. 4)
Lepidorbitoides sp. (with rhomboid equatorial chambers)
Amphistegina sp. (different from the species from the Murphys beds)

3. Murphys beds of the Upper Scotland Formation (Lower Middle Eocene)

S. 34c (type locality of the Murphys beds; material collected by the author and others) (see also Vaughan 1945)
Ranikothalia antillea (Hanz.)
Ranikothalia tobleri (Vaughan and Cole)

[8] The name *Hexagonocyclina*, under which a similar form has been described from Venezuela (Caudri 1944, pp. 362–363) is for several reasons invalid. A discussion of this subject will be prepared in the near future. Meanwhile, a new name: *Bontourina*, is proposed and I designate as type species *Bontourina inflata* n. sp., the small robustly lenticular Trinidad form mentioned on p. 363 of that same paper. Figures of that species are presented herewith (Pl. 73, fig. 6 and Pl. 74, fig. 5), of which the latter illustrates the holotype). The type locality, Point Bontour, Caudri 18, Trinidad, is of Upper Eocene age (Mount Moriah silt, see Kugler 1938), but the specimens of *B. inflata*, and of *B. meandrica* (Caudri) which accompanies it, are to be considered as reworked from the Paleocene, together with several specimens of *Ranikothalia* and *Discocyclina*. Apart from these loose specimens, there are also embedded in the silt (at the same locality) large blocks of Paleocene limestone which carries the same species (see below). *B. inflata* and *B. meandrica* occur also in the Paleocene of Soldado Rock; *B. meandrica* was originally described from the Paleocene of Guárico, Venezuela (Caudri 1944).

It is possible that *Bontourina* is nothing more than a subgenus of *Lepidorbitoides* but this needs more detailed study. Its remarkable quadriserial nepiont, in addition to the chiefly hexagonal shape of its equatorial chambers, bars it from being included in *Discocyclina*.

EXPLANATION OF PLATE 74

FIGS. *1, 4, 7*—*Sulcoperculina vermunti* Thiadens, ×47, from the Guaduas limestone (Maestrichtian, Upper Cretaceous) near Guaduas, Cundinamarca, Colombia, *1*, a rolled specimen (compare with *4*), Tropical Oil Company coll. no. 27257; *4*, and *7* are views of no. 27367. (p. 480)

2—*Lepidorbitoides* sp., ×47, from the Valle Hondo formation (Paleocene or Lower Eocene), Trujillo, Venezuela. (p. 479)

3—*Ranikothalia antillea* (Hanzawa), ×47, from the Valle Hondo formation (Paleocene or Lower Eocene), Trujillo, Venezuela. (p. 479)

5—*Bontourina inflata* Caudri, n. gen., n. sp. Holotype, ×42, horizontal section of a reworked specimen derived from the Paleocene, in the Mount Moriah silt (Upper Eocene) at Point Bontour, Trinidad. (p. 477)

6—*Lepidorbitoides* sp., ×47, from the Guaduas limestone (Maestrichtian, Upper Cretaceous) near Guaduas, Cundinamarca, Colombia. (p. 480)

Discocyclina barkeri Vaughan and Cole
Discocyclina barkeri var. (with polygonal equatorial pattern in center)
Discocyclina grimsdalei Vaughan and Cole
Discocyclina aguerreverei Caudri
Discocyclina fonslacertensis Vaughan
Discocyclina cf. bullbrooki Vaughan and Cole
Discocyclina anconensis Barker (abundant)
Discocyclina sp. ind. div.
Asterocyclina sp. div. (also typical *A. asterisca* Güppy)
Proporocyclina schomburgki Vaughan
Proporocyclina perpusilla ? Vaughan (or. *P. tobleri ?* Vaughan and Cole)
Lepidorbitoides cf. planasi Rutten, A- and B-forms
Leipidorbitoides sp. (with rounded equatorial chambers)
Sphaerogypsina sp.
Amphistegina senni Vaughan
Amphistegina sp. ind. (heavily pillared species with very slanting septa, without counterseptal hooks)
? Orbitolinoides senni Vaughan

Note: Vaughan also lists from other localities in the Murphys beds:
Discocyclina harrisoni Vaughan
Asterocyclina barbadensis Vaughan
Orbitolinoides senni Vaughan

II. Trinidad (including Soldado Rock)

1. Soldado Rock, Soldado Formation (Paleocene)

Lepidorbitoides was not actually found in place in the Soldado Paleocene, but it was encountered in the transgressive Upper Eocene "rubble bed" (K. 2951b, see Kugler 1938, p. 215), the very rich fauna of which consists nearly exclusively of Paleocene specimens derived from the underlying beds with only a very scanty sprinkling of Upper Eocene forms. The same applies to *Discocyclina fonslacertensis* and *D. caudriae* at this locality (see below).

The Paleocene of this very small islet, which was chosen as the type locality of the Soldado Formation (equivalent of the Midway) in Central and South America, contains the following species:

Ranikothalia antillea (Hanz.)
Ranikothalia tobleri (Vaughan and Cole)
Ranikothalia soldadensis (Vaughan and Cole)
Discocyclina barkeri Vaughan and Cole, A- and B-forms
Discocyclina barkeri, var. (with polygonal equatorial pattern in center)
Discocyclina grimsdalei Vaughan and Cole, A- and B-forms
Discocyclina aguerreverei Caudri
(*Discocyclina ? caudriae* Vaughan)
(*Discocyclina fonslacertensis* Vaughan)
Athecocyclina soldadensis Vaughan and Cole
Bontourina inflata n. sp.
Bontourina meandrica (Caudri)
(*Lepidorbitoides cf. planasi* Rutten)
Amphistegina sp. (thickwalled species, not belonging to the group of *A. lopeztrigoi* Palmer)

From a higher level of the Paleocene or perhaps from the Lower Eocene, but found (reworked?) high up in the Upper Eocene section on the same islet (K. 3878, see Caudri 1944, p. 385–386):
Discocyclina bullbrooki Vaughan and Cole
Proporocyclina tobleri Vaughan and Cole
Amphistegina sp. div.

2. Point Bontour, 1 mile S. of San Fernando, Trinidad (Paleocene block in the Upper Eocene Mount Moriah silt; Pl. 73, figs. 3, 5–10; Pl. 74, fig. 5)
Ranikothalia antillea (Hanz.) (also found in loose specimens in the matrix)
Discocyclina barkeri Vaughan and Cole (not in the block itself, but in loose specimens in the matrix)
Discocyclina grimsdalei Vaughan and Cole
Discocyclina aguerreverei Caudri
Discocyclina fonslacertensis Vaughan
Athecocyclina soldadensis Vaughan and Cole (including var. *calebardensis* Vaughan)
Bontourina inflata n. sp. (in block and also in loose specimens in matrix; Pl. 73, fig. 6 and Pl. 74, fig. 5)
Bontourina meandrica (Caudri)
Lepidorbitoides cf. planasi Rutten (in block and also in loose specimens in matrix) (Pl. 73, fig. 9)

3. Dunmore Hill vicinity, South Trinidad (Navet Formation, Lower? Eocene; compare Senn 1940, p. 1580)

Ranikothalia tobleri (Vaughan and Cole)
Discocyclina barkeri Vaughan and Cole
Discocyclina barkeri, var. (with polygonal equatorial pattern in center)
Discocyclina grimsdalei Vaughan and Cole
Discocyclina cf. aguerreverei Caudri
Discocyclina bullbrooki Vaughan and Cole
Asterocyclina ? sp.
Pseudophragmina (Proporocyclina?) cf. advena (Cushm.)
Proporocyclina tobleri Vaughan and Cole (including some specimens with monstrously thick walls)
Proporocyclina perpusilla Vaughan
Athecocyclina soldadensis ? (Vaughan and Cole
Lepidorbitoides cf. planasi Rutten
Operculinoides soldadensis Vaughan and Cole
Amphistegina sp. (reminding of the species from Soldado Rock, K. 3878)

4. Biche, East Trinidad, Calyx 50 and 50A (age between Paleocene and Upper Eocene, or: Upper Eocene with reworked older forms)

Ranikothalia antillea (Hanz.)
Discocyclina anconensis Barker
Lepidorbitoides cf. planasi Rutten
Helicolepidina cf. spiralis Tobler
? Lepidocyclina (Isorbitoina) sp.
?? Eulinderina (or *Polylepidina?*) *sp.* (with a long uniserial nepionic spiral)
Amphistegina sp. (heavily pillared; belonging to the group of *A. lopeztrigoi* Palmer *?*)

III. Venezuela

1. Limestone of San Jun de los Morros, State of Guárico (Paleocene) (see Caudri 1944)

Ranikothalia antillea (Hanz.)
Ranikothalia tobleri (Vaughan and Cole)
Ranikothalia soldadensis (Vaughan and Cole)
Discocyclina aguerreverei Caudri
Athecocyclina cf. cooki (Vaughan)
Bontourina meandrica (Caudri)
Lepidorbitoides cf. planasi Rutten (Pl. 73, fig. 11)
Lepidorbitoides sp. ind. (with ogival equatorial chambers)

2. Limestone sample from the Valle Hondo Formation (Guasare Formation of Sutton, Bull. A.A.P.G. 1946, see p. 1658), 1.9 km. E. of Casa de Zinc, La Concepción-La Cuchilla Road, State of Trujillo (Paleocene). (Coll. J. W. Durham, Tropical Oil Company coll. No. 19155.)

Ranikothalia antillea (Hanz.) (Pl. 74, fig. 3)
Ranikothalia cf. tobleri (Vaughan and Cole)
Discocyclina grimsdalei Vaughan and Cole, or *D. aguerreverei* Caudri
Discocyclina cf. caudriae Vaughan
Lepidorbitoides cf. planasi Rutten (Pl. 73, fig. 2)
Lepidorbitoides sp. (with arcuate equatorial chambers) (Pl. 74, fig. 2)

These lists show that the commonest species of *Lepidorbitoides* found in the Tertiary of the Caribbean region is *L.* (*Orbitocyclina*) cf. *planasi* Rutten. Direct comparison of specimens with the types of Rutten's Cuban *L. planasi* is necessary to determine whether these forms are identical; if not, Vaughan's specific name: *L.* (*Orbitocyclina*) *barbadensis* (Vaughan) should be used. Of all known *Orbitocyclinas*, this species shows the greatest resemblance to *Polylepidina* on account of its open-arcuate or rounded broad-hexagonal median chambers. Nevertheless, it is hardly possible to confuse it with true *Polylepidina*, for the whole structure of both the equatorial and the lateral chambers is so much finer that at first sight one might compare this form with *Discocyclina* rather than with the much coarser *Polylepidina* and primitive species of *Isorbitoina* (compare Pl. 73, figs. 1, 2, 9 and 11 with figs. 3, 5, 7, and 8). Perhaps if all the species

of *Lepidorbitoides* were figured side by side with all comparable species of *Lepidocyclina* at exactly the same scale (and not as done by Tan who, in order to obtain equally-sized figures, used highly magnified photographs of *Orbitocyclina* on the same page with less magnified figures of *Polylepidina*), some general differences between the two genera might become apparent.

APPENDIX

Age of the Guaduas Formation in Colombia

The Guaduas formation in the Middle Magdalena area of Colombia (Department of Cundinamarca, west of Bogotá), which is considered to be Upper Cretaceous or in part Tertiary, contains a few fossiliferous limestones and calcareous sandstones that are of special interest for its age determination. Some of these rocks are typical ammonite sandstones and *Siphogenerinoides*—limestones and there seems to be no doubt about their Cretaceous age. But the main limestone zone which, as lens-like intercalations in a locally well-developed conglomerate, can be followed in the field for some 30 kilometers is still the subject of much controversy. This zone, which may be termed the Guaduas limestone, contains in several places an abundant fauna of orbitoids and other "larger" Foraminifera and seems to lie slightly higher in the section than the other fossiliferous beds. Field relations tempt the geologist to interpret the conglomerate as a basal deposit succeeding a gap in sedimentation coinciding with the Cretaceous-Tertiary boundary; the conglomerate and the orbitoidal limestone might thus be referred to the Tertiary, even to the Eocene rather than to the Paleocene.

A superficial paleontological examination, e.g. with a hand lens, seems to corroborate a Tertiary age, for the structure of the orbitoids is very fine, as in *Discocyclina*, and the other forms, with which they are associated, look like some species of *Amphistegina*. Even the first microscopic examination may be misleading because the many vertical orbitoid sections are very similar to *Discocyclina* and the less frequent horizontal ones, which are badly recrystallized, seem to show rectangular median chambers. Also, occasional more or less horizontal sections of a *Ranikothalia*-like form occur, which strengthens the impression that the limestone is of Tertiary age. However, careful study shows that: 1. some specimens and fragments of the "*Discocyclina*" actually possess median chambers of the arcuate type (Pl. 74, fig. 6) so that it becomes clear that the apparently rectangular shape in most specimens is due to crystallization; 2. the peripheral edge of the "*Amphistegina*" is consistently "broken off" and in many specimens shows definite indentation (Pl. 74, fig. 7); 3. the "*Ranikothalia*" is too small and delicate to be typical (compare Pl. 73, figs. 1, 4 and 7 with fig. 3).

These observations reveal that the "*Discocyclina*" is actually *Lepidorbitoides* (probably represented by two different but indeterminable species) while the accompanying form ("*Amphistegina*" and "*Ranikothalia*" combined) is *Sulcoperculina* (*S. vermunti* Thiadens). This fauna is of Maestrichtian age, comparable to that of the Habana formation of Cuba and the Cárdenas beds in Mexico.

In attempting to coordinate this information and the field data the possibility of reworking must be considered. Although some of the specimens of *Lepidorbitoides* are slightly rolled or broken and enclosed by black lines and one of the samples has a somewhat brecciated aspect and includes tiny fragments of limestone carrying the same *Lepidorbitoides*, this limestone shows no certain evidence of reworking. The seemingly weathered condition of the fossils and the pseudobrecciated nature of the rock may indicate deposition under rough-water conditions around a half-consolidated reef. Moreover, no authochthonous Maestrichtian sediment with this same faunal assemblage is known anywhere in Colombia from which such a large amount of material could have been derived.

Consequently the conclusion seems reasonable that the age of the Guaduas limestone (and the conglomerate) is Maestrichtian. This does not mean, however, that the Guaduas formation as a whole does not also comprise deposits of Tertiary age.

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TWO NEW MARINE OSTRACODES FROM THE TERTIARY OF WASHINGTON

I. G. SOHN
U. S. Geological Survey, Washington, D. C.

ABSTRACT—Two new species of Ostracoda from the Lincoln formation of Washington are described: *Cythereis lupheri* and *Cythereis porterensis*.

INTRODUCTION

THIS is the first time that ostracodes are described from the marine Tertiary of western Washington. Preliminary examination of samples of sediments from the Lincoln formation indicates that well-preserved ostracode faunas are present. The two species described are from a fauna represented by at least four genera of Ostracoda, several genera of Foraminifera,[1] and ophiuroid vertebrals. The two species were chosen for description because of their abundance.

The specimens are from five samples of thick-bedded siltstones collected by Dr. R. L. Lupher, geologist, Shell Oil Company, in the SW¼ sec. 27, T. 17 N., R. 5 W., Grays Harbor County, Washington, along a highway cut from 3200 feet to 4000 feet southeast of the town of Porter. The samples fall within a stratigraphic range of about 150 feet in the lower part of the Porter section of the Lincoln formation and are from the "*Turritella porterensis* zone" in Durham's Oligocene sequence.[2] The two new species are abundant in the upper three samples.

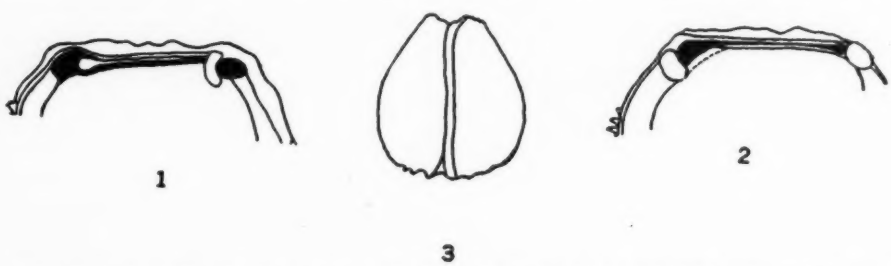
The writer is grateful to Dr. R. L. Lupher for the samples and to Dr. John B. Reeside, Jr. for assistance. The photographs were made by Mr. N. W. Shupe, and the drawings by Mrs. Elinor Stromberg, both of the U. S. Geological Survey.

The types are deposited at the U. S. National Museum.

Order OSTRACODA Latreille
Suborder PODOCOPA Sars
Family CYTHERIDAE Baird, 1850
Genus CYTHEREIS Jones, 1849

For the purpose of this paper the writer accepts the definition of the genus as given by Alexander (1933, pp. 208, 209) but, as so recognized, *Cythereis* is actually a form genus to which unrelated species have been assigned. Students of Recent Ostracoda distinguish the genus by the appendages and have recognized several groups or subgenera all of which have similar carapaces.

In the original description, Jones (1849, pp. 9, 14, 15) noted that the hinge of the left valve is grooved. Alexander, on the other



FIGS. *1–3—Cythereis lupheri* Sohn, n. sp., *1, 2*, hinge elements of left and right valves; *3*, camera-lucida drawing of Anterior view, magnification approximately ×35.

[1] See Weldon, W. Rau, 1948, Jour. Paleontology, vol. 22, pp. 152–174.
[2] Lupher, R. L. (personal communication May 27, 1946).

hand, reported that the right valve is grooved. Most writers in recent years have followed Alexander in this respect, although Van Veen (1936, p. 132) stated that there is a weak groove on the left valve. Swain (1946 pp. 376, 377) described *C. bicarinata* and *C. chinsegutensis*, in which there is a weak groove in the left valve. One of the following new species, *C. lupheri*, has a very faint groove on the hinge bar of the left valve.

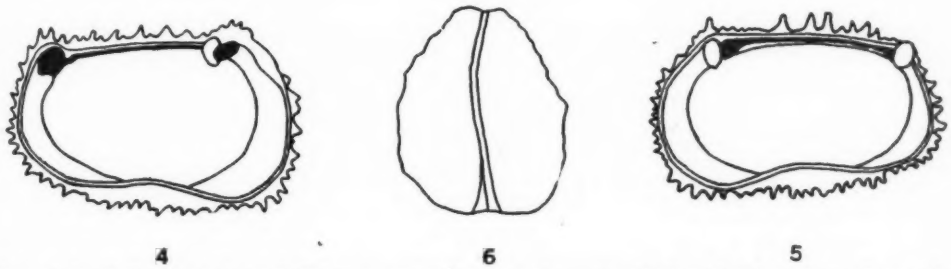
CYTHEREIS LUPHERI Sohn, n. sp.
Plate 75, figures 1–5; text figures 1–3

Carapace subovate in side view, highest near front. Dorsal margin marked by four crenatures which diminish in size posteriorly. The first is formed by the anterior cardinal angle, the other three by projections of the reticulate surface above the hinge line. Hinge line straight, invaginated. Ventral margin gently convex, sloping upward posteriorly. Anterior margin broadly rounded, ventral portion denticulate. Posterior margin angled at about midline; upper half of margin sloping up and forward to make an obtuse angle at the junction with dorsal margin; lower half denticulate, almost straight, curved broadly to join the upward-curving ventral margin. Ventral outline subhexagonal, anterior sides begin at plane of anterior cardinal angle, middle sides gently convex, extend behind the three-quarter plane whence the posterior sides begin to converge backwards to meet at a more obtuse angle than the anterior. Dorsal outline similar to ventral. Anterior outline pyriform with the flat venter at base.

Valves tumid, surface reticulate. Reticulations coarse, oval to hexagonal in shape, arranged in rows which tend to parallel the margins. Stubby spines occur in the postventral area. Eye tubercle present, not very prominent.

Interior of valves deep; external reticulations visible internally. Line of concrescence and inner margin approximately coincide, parallel to margins. Marginal area relatively narrow, variable in width, in some specimens about half as wide as in others. Selvage faintly fluted, narrow along end margins, wider along venter where it flexes inward approximately in front of middle. Radial pore canals numerous, simple. The right valve has a stronger flexure and a low node outside and behind that flexure. Muscle scar pattern consists of a vertical row of four oval scars, with a fifth oval scar sloping forward in front of the top two.

Hinge of the right valve consists of two smooth well-developed terminal teeth, an anterior comma-shaped tooth curving down and backward to surround a socket, and a posterior tooth elongated parallel to the hinge line. A narrow, shallow groove extends from the socket to the posterior tooth immediately in front of which it expands into a small socket. The left valve has a deep anterior socket followed by a strong knob-like tooth which is connected to a posterior socket by a faintly grooved bar. This bar constitutes the dorsal margin of the valve and widens posteriorly as a counterpart to the groove in the right valve. The posterior socket is open towards the inside of the valve.



FIGS. *4–6*—*Cythereis porterensis* Sohn, n. sp., *4*, *5*, hinge elements of left and right valves; *6*, anterior view, outline traced from a photograph, magnification approximately ×40.

Dimensions.—

	Length	*Height (behind anterior cardinal angle)*	*Width (on ventral side)*
Right valve:			
Holotype	0.931 mm.	0.559 mm.	
Left valve:			
Holotype	0.941 mm.	0.559 mm.	
Complete Carapace:			
Paratype	0.960 mm.	0.55 mm.	0.50 mm.

Holotype: U. S. National Museum 560158.
Paratypes: U. S. National Museum 560159.

Remarks.—This species is distinguished by the crenate dorsal margin and the knob on the venter behind the flexure of the right valve.

CYTHEREIS PORTERENSIS Sohn n. sp.
Plate 75, figures 6–11; text figures 4–6

Carapace subquadrate, highest near front, spinose along all margins. Dorsal margin straight; ventral margin gently convex; anterior margin broadly rounded; posterior margin straight, sloping down and backward so that the posterior ventral area, which is rounded, is hindmost. Anterior cardinal angle has a small backward projecting spine. Dorsal outline suboctagonal, ends about one-half greatest thickness, sides slope from both front and rear towards gently convex central portion, greatest thickness in posterior half. Surface of valves reticulate, with stubby spines at the intersections of the sides of many of the reticules. A tuft of larger spines points out and backwards from the post-ventral area. Eye spot hemispherical, glassy, located near the anterior cardinal angle. Anterior outline pyriform with the flat venter at base.

Interior of valves quadrate in outline, deep inside, reticulations visible. Muscle scar pattern obscure. Line of concrescence and inner margin approximately coincide, parallel to the margins. Selvage narrow along end margins, widens on venter where it flexes inward in front of middle. Radial pore canals numerous.

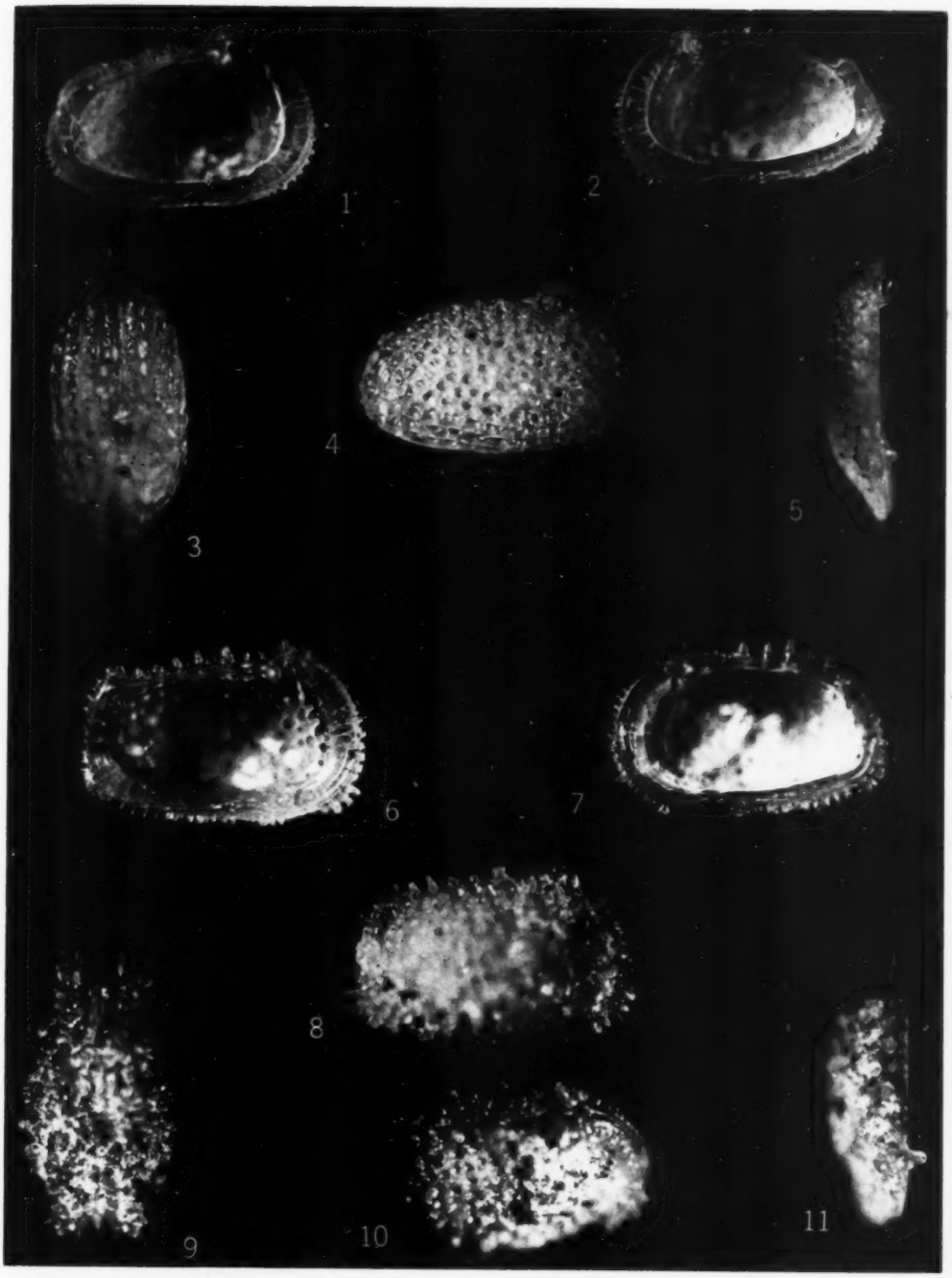
Hinge of right valve consists of two smooth well-developed terminal teeth, an anterior tooth that is comma-shaped and curves backwards to surround a socket, a posterior tooth that terminates in an elongated knob the long axis of which is parallel to the hinge line and extends to the posterior dorsal corner. A narrow, shallow groove connects the socket to the posterior tooth. The groove expands to form a shallow socket adjacent to the tooth. Left valve has an anterior socket behind which is a tooth which is connected by a very narrow bar to the posterior socket. The bar terminates in a minute tooth adjacent to the socket.

EXPLANATION OF PLATE 75

(All figures approximately ×40.)

FIGS. *1–5*—*Cythereis lupheri* Sohn, n. sp. *1*, *2*, inside views of left and right valves of the holotype, a complete carapace that was opened and separated. *3*, *4*, paratype, a complete carapace, ventral view oriented with anterior end below and lateral view of right valve. *5*, paratype, dorsal view of right valve showing hinge and dorsal outline, oriented with anterior end below. (p. 483)

6–11—*Cythereis porterensis* Sohn, n. sp. *6*, *7*, inside views of left and right valves of the holotype, a complete carapace that was opened and separated. *8–10*, paratype, a complete carapace: *8*, lateral view of right valve; *9*, ventral view oriented with anterior end above; *10*, inclined view of right valve showing hinge line and anterior. *11*, paratype, dorsal view of right valve showing hinge, oriented with anterior end below. (p. 484)



Sohn, Tertiary Ostracodes

Dimensions.—

	Length (*base of spines*)	*Height* (*behind anterior cardinal angle*)	*Width*
Right valve:			
Holotype	0.95 mm.	0.539 mm.	—
Left valve:			
Holotype	0.95 mm.	0.549 mm.	—
Complete Carapace:			
Paratype	0.96 mm.	0.55 mm.	0.53 mm.

Holotype: U. S. National Museum 560160.
Paratypes: U. S. National Museum 560161.

Remarks.—This species is distinguished by the square outline and by the large postventral spines. Specimens of this species vary in size, some being longer and narrower than others. A graph constructed with the height plotted against the width for 17 specimens had all the points fall within one group, indicating that the difference in size is due to individual variation rather than sexual dimorphism.

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JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 4, PP. 486–487, PL. 76, JULY 1948

CRIBROPARELLA, A NEW GENUS OF FORAMINIFERA FROM THE UPPER MIOCENE OF ALGERIA*

ABRAHAM TEN DAM
Relizane, Algeria

STUDY of the extremely rich microfaunas from the blue marls of the Upper Miocene in western Algeria has yielded a very interesting new genus of Foraminifera closely related to and probably descended from *Pulvinulinella* Cushman 1926 or *Parrella* Finlay 1939.

Superfamily ROTALIIFORMES Brotzen 1942

Family DISCORBIDAE
Subfamily DISCORBINAE
Genus CRIBROPARELLA ten Dam, n. gen.
Genotype *Cribroparella regadana*
ten Dam, n. sp.

Test trochospirally coiled, biconvex, peripheral margin angular or carinate, umbilicus usually closed by overlapping chambers. All chambers visible dorsally, only those of last coil visible from ventral side. Sutures depressed or limbate, on dorsal side oblique, nearly radial ventrally. Wall smooth, finely perforate. Aperture on ventral side of peripheral face, of two types; normal aperture a narrow slit or oval opening between periphery and closed umbilicus, other type cribrate; consisting of numerous circular openings all over septal face. The cribrate supplementary aperture distinguishes this from other similar genera.

Occurrence.—Upper Miocene of western Algeria.

Remarks.—It is difficult to place this new genus in Cushman's classification (1940). Its general form and to a lesser degree its normal aperture suggest that it is closely related to *Pulvinulinella* Cushman. The normal aperture, however, also suggests close relationship to *Parella* Finlay, but it seems impossible to refer both genera to the family Cassidulinidae to which Cushman assigns *Pulvinulinella*. In Glaessner's classification (1945) this genus falls readily into the subfamily Discorbinae, and may be interpreted as having developed from *Pulvinulinella* or *Parella*. In Brotzen's classification (1942) of the superfamily Rotaliiformea (Rotalidea Glaessner 1945) it would be referred to the family Epistominidae (almost identical with the Ceratobuliminidae Glaessner) and might be derived from either *Pulvinulinella* or *Parella* by the development of a cribrate supplementary aperture or, as Brotzen puts it, a cribrate "areal" aperture. It is not reasonable, however, to include genera such as *Parella*, *Pulvinulinella*, and *Cribroparella* without supplementary chambers, in a single family with others which are characterized by internal subdivision of the chambers. I am inclined, therefore, to accept Glaessner's classification and assign *Parella*, *Pulvinulinella*, and *Cribroparella* to Glaessner's family Discorbidae, subfamily Discorbinae.

CRIBROPARELLA REGADANA ten Dam,
n. gen. n. sp.
Plate 76, figures 1–3

Test trochospirally coiled, biconvex, peripheral margin distinctly carinate. Umbilicus closed by somewhat overlapping chambers, covered with callous growth of clear shell material. All chambers visible on dorsal side, only those of last formed coil ventrally. Dorsal side showing 2½ to 3 coils with 12 to 14 chambers in last coil of adult specimens. Chambers strongly oblique, sutures limbate, level with surface, only very slightly depressed between last 3 or 4 chambers. Ventral side showing 12 to 14 chambers which are gently curved, somewhat overlapping in umbilical region, sutures somewhat limbate, slightly depressed, almost radial, gently curved. Walls smooth, calcareous, finely perforate. Apertures on ventral side of peripheral face, of two types. Normal aperture an oval opening with phialine lip between periphery and closed umbilicus, supplementary aperture cribrate, consisting of numerous circular openings all over septal face.

Dimensions.—Diameter, 1.35 mm., thickness 0.50 mm.

Holotype.—ten Dam Coll. no. A238h.

Occurrence.—Rather common, locally, in

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the Upper Miocene at Aïn Regada, western Algeria; elsewhere rare in the Upper Miocene of Algeria. Type locality is Aïn Regada, surface sample in the blue marls of the Upper Miocene.

Remarks.—In broken specimens one can observe that the openings of the cribrate aperture are nearly all filled with secondary shell material, but the normal aperture is not. All very young specimens have a normal aperture and at most only very few openings of the cribrate supplementary aperture and thus closely resemble certain species of *Parrella* and *Pulvinulinella*. Ontogeny, therefore, seems to prove the close relationship of *Cribroparrella*, *Parrella*, and *Pulvinulinella*.

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JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 4, PP. 488–489, PL. 76, JULY 1948

TWO UNDETERMINED NEW ZEALAND TERTIARY FOSSILS

J. A. BARTRUM
Auckland University College

IN THE upper mid-Tertiary beds of Auckland, New Zealand, and its vicinity the writer has found fossils of two organisms of unknown nature. Both have been submitted to a number of paleontologists overseas, but with the sole result that authorities of a world-famous museum have regarded one of them as crustacean trails, although there appear to be very good reasons why this cannot be so.

The first of these fossils (Pl. 76, figs. 4 and 5) occurs very sparsely in tufaceous sandstones at Muriwai on the coast west of Auckland City. Over many years the writer has seen only four specimens, all of the same general nature; though figured is by far the largest. It was located by a student of this College, Mr. W. E. Russell, during a class excursion and was found associated with sparse marine gastropods and lamellibranchs and fairly numerous pteropods of the genus *Vaginella*. It measured 8 ins. in length when discovered but part of its undivided tube was destroyed during extraction from the rock, reducing it to 5.2 ins. Its segmented portion has 15 subequal joints in its length of 21 mm.

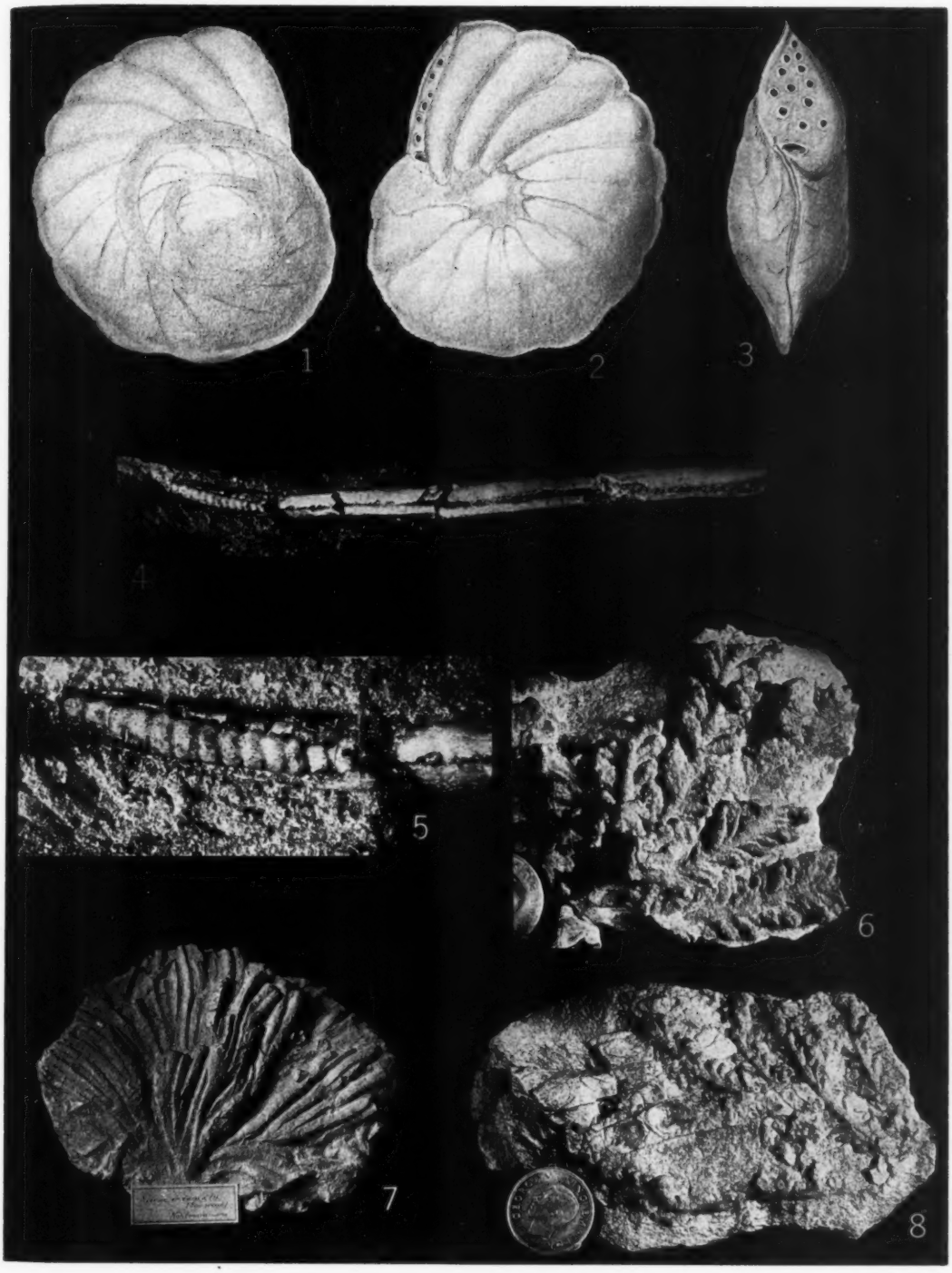
Of the four specimens two others resemble the one figured in having an undivided fairly straight calcareous tube open at one end and terminating in a slightly curved segmented portion. In the remaining one, however, which was destroyed during return from overseas, the undivided tube was bent almost at right angles and then broken away about an inch from its segmented continuation. The segmented portion, ¾ in. in length, showed six joints which decreased in size towards the apex in such manner as to indicate that, although this latter was incomplete, it is unlikely that the original number of segments was more than seven. The cross section of the main tube appears to be broadly oval, as is indicated by the blunt eroded edge exhibited in figure 4. If provisionally the unsegmented portion of the shell be regarded as anterior, the posterior end of each segment appears to be convex and to rest in a socket made by the anterior end of the succeeding segment. The writer was unable to determine whether or not there were septa at the joints; one specimen that he broke failed to show any, though conceivably thin septa may have existed originally and have been destroyed prior to the filling of the shell by sediment. Each segment is made of an inner calcareous layer which is enwrapped by an outer one. The latter has been mostly eroded from the specimen figured, although remnants of it are clearly visible in figure 5. Close inspection of this photograph will show that the outer layer is almost complete over the first and possibly the second segment. It also continued over the undivided tube, on whose lower side a remnant of the outer layer persists, as illustrated in figure 5. There, however, it does not appear to have been separated from the inner layer, whereas in the segments a thin smear of sediment intervenes between the two layers.

The writer wonders if this fossil possibly represents a cephalopod allied to the modern *Spirula*. Conceivably it may be an appendage, such as an antenna, of a crustacean. Or is it possible that some annelids developed tubes of this type? Any suggestions as to the nature of this organism from

EXPLANATION OF PLATE 76

FIGS. *1–3*—*Cribroparella regadana* ten Dam, n. gen., n. sp., dorsal, ventral, and lateral views ×30. (Spelling of generic name on plate 76 is erroneous.) (p. 486)

4–8—Undetermined New Zealand Tertiary fossils. *4*, undetermined fossil from Auckland; length 5.2 inches; *5*, segmented portion of the same specimen ×2.5; *6*, undetermined fossil from same region and age ×½ (coin is 31 mm. across); *7*, a questionable sponge found plentifully in close association with fossil showing in *6*, *7*, about ⅛ natural size; *8*, another specimen of fossil shown in figure *6*. (p. 488)



ten Dam, *Dribroparella*
Bartrum, New Zealand Tertiary fossils

persons who have seen similar specimens will be most welcome.

The other fossil about which the writer desires information that may lead to identification is portrayed in figures 6 and 7. It is abundant in sea-cliffs of upper mid-Tertiary sandstones with minor intercalated mudstones between Narrowneck and Takapuna beaches near Auckland, but has not so far been noted elsewhere. It occurs typically in slabs about a foot in width and seldom more than about an inch in thickness composed of limonitized casts of what the writer takes to be fossil sponges (Fig. 8). Like these, it invariably is represented by casts of sediment strongly cemented by limonite when found in exposures where oxidation has occurred. What is regarded as an important associated feature is that the adjacent sediment of the enclosing bed invariably is poorly coherent, for it is almost without cementing limonite, so that the fossils stand out in sharp relief. A few of the fossiliferous slabs have not been converted wholly to limonite, but preserve unoxidized cores rich in carbonate of iron. A sewage tunnel cut through unweathered sediment in this locality yielded a number of unoxidized specimens both of the "sponges" and of the other fossils.

In detail these unidentified fossils (figs. 6 and 7) are somewhat feather-like structures generally of very uniform size with a width of from 14 to 22 mm., a length seldom exceeding 10 cm. and a thickness of about 3 mm. Rare individuals of more delicate nature may not exceed 7 mm. in width. Each "plume" has a central rounded axis from which closely-set pairs of short stumpy branches, given off one opposite the other, diverge at acute angles and all have strongly bulbous terminations. Upper and lower surfaces of the main axis and of the "branches" alike are convex.

As already stated, it has been suggested in authoritative quarters that these fossils represent crustacean trails. Rare examples of what appear to be such trails occur in the same beds, but they are quite distinct in character. One specimen of a "trail" that was collected is practically an enlarged replica of *Nereites cambrensis* M'Leay figured in Zittel's *Text-book of Palaeontology*. The fossils now described cannot be trails for several reasons. In the first place they are casts of bodies with definite upper and lower surfaces, whereas the trails of crustaceans or gastropods are merely superficial impressions. Secondly it is most unlikely that the filling of the depressions of trails could become limonitized while the surrounding sediment did not. Selective limonitization is readily explicable, however, if as with the associated "sponges," the decaying organic matter of the bodies in question was replaced during sedimentation largely by carbonate of iron and in later oxidation, this would be converted to the hydrate of iron. A final demonstration that these fossils are not trails is given by the fact that groups of superimposed individuals occur in which some of the upper ones have arched over those beneath. Such superposition is shown in figure 6, although the uparching, which is prominent in the actual specimen, is not clearly apparent in the photograph.

In conclusion the writer tentatively suggests that the organism represented may have been a sponge or a sea weed. It has some of the characteristics of hydroids, but the size seems too great for its inclusion in this group.

JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 4, PP. 490–493, PL. 77, 8 TEXT FIGS., JULY 1948

NOTES ON *PHANOCRINUS* FROM THE FAYETTEVILLE FORMATION OF NORTHEASTERN OKLAHOMA

HARRELL L. STRIMPLE
Bartlesville, Oklahoma

ABSTRACT—A collection of *Phanocrinus* specimens from the Fayetteville formation of northeastern Oklahoma is of considerable interest because anal variations are found much like those observed by James Wright among Scottish specimens. One new species is described.

INTRODUCTION

FOR several years I have accumulated specimens of *Phanocrinus* from the Fayetteville formation (Upper Chester) in outcrops southwest of Afton, Craig County, Oklahoma and now have some three hundred specimens available for study. This is a smaller number than was observed by Wright (1926) for *Phanocrinus calyx* (McCoy), and is infinitesimal compared to the multitude of individuals that must have lived in this vicinity. Nevertheless this is a substantial number and this series of specimens provides additional information supporting the observations made by Wright. In discussing the genus *Phanocrinus*, Kirk (1937, p. 603) took note of the variations in anal plates described by Wright but considered it probable that the Scottish forms were, "An unusually variable and plastic group. It is probable that in this case we are dealing with new arrivals that are responding to the stimulus of changed environment. Certainly no comparable variation of structures has been found in the American specimens examined by me, although nearly as many specimens have been available for study." Only ten per cent of my specimens show modifications of this structure whereas twenty-three percent of Wright's were variable, but I consider it highly significant that the same type and proportionate number of modifications occur.

Another more recent study of *Phanocrinus* and allied forms has been made by Sutton and Winkler (1940) but these authors disregarded the warning given by Wright's work and concluded that the shape and arrangement of the anal plates in the *post.* IR is of specific value. The anal structure might be of specific or even generic value but all other characters also must be carefully considered. The number and structure of arms is important but here again much care must be exercised. I have one specimen in which the bifurcation of the anterior ray takes place above the second primibrach whereas all other rami bifurcate above the first primibrach, the later condition being typical for the genus. If only the PBrBr were preserved, as often happens, this specimen would be taken for a nine armed form and considered a separate species provided other factors were not taken into account. Therefore, I believe that at least some of the nine armed forms may be abnormal representatives of regular ten armed species.

Kirk interpreted this genus as including forms with five to ten arms and one might expect at least some representatives with six, seven or eight arms but I have neither observed nor seen descriptions of such specimens. Sutton and Winkler (1940) proposed the genus *Pentaramicrinus* for the reception of species with only five arms and I am inclined to accept this as a valid genus. Difficulty might be incurred in studying only calices but this is true in many genera.

I am deeply obligated to Mr. James Wright for his kindness during my stay in Scotland at which time I was able to study his marvelous collection and come to a better understanding of many crinoid problems. Mr. Wright also has been kind enough to read and criticize this manuscript. Many of the specimens used in this study were collected by Mr. Claude Bronaugh of Afton, Oklahoma. The beautiful crown, chosen as holotype for *Phanocrinus alexanderi* n. sp.,

was found by Mr. Richard Alexander of Collinsville, Oklahoma, and a paratype was collected by Dr. L. R. Laudon, of the University of Kansas. Many other specimens were collected by my wife, Mrs. Melba Strimple.

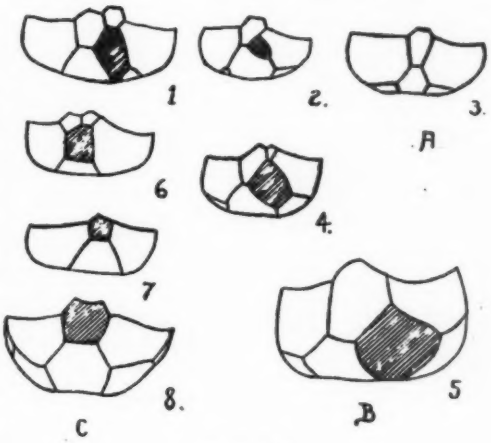
I have not attempted to identify specifically all of the specimens used in the study of modifications in the *post.* IR at this time because I do not have a sufficient number of well preserved crowns to adequately determine all of the species that may be involved. However, most of the specimens are assignable to *P. alexanderi* n. sp., *P. cylindricus* (Miller and Gurley) and *P. formosus* (Worthen). Wright assigned all the thousand specimens used in his study to *Phanocrinus calyx* (McCoy) and after seeing all the gradations in shape and size of calices, it was easy for me to understand his reason for doing so. I am convinced, however, if the arms of all of these specimens were known more than one species could be distinguished.

MODIFICATION IN THE ANAL STRUCTURE

The classification of modifications used by Wright (1926) is followed here with the addition of another group of variations in which there is loss of contact between RA and RX. I consider this condition to be of primary importance because it must have been through some such stage that forms like *Ulocrinus* and *Ethelocrinus* evolved within their respective families.

Normal type, consists of specimens in which anal X rests solidly on post. B and RA is in contact with r. post. B, figure 1.

Normal type A, has anal X still in contact with post. B but the lower extremity of RA has become separated from r. post. B, figure 2.



FIGS. 1–8

Extreme type, includes forms whose RA has effected contact with the 1. post. R so that anal X is pushed upward and has lost contact with post. B. The lower extremity of RA remains in contact with r. post. B. Nearly approached by figure 4.

Extreme type A, wherein RA has effected contact with 1. post. R as in "Extreme

	Fife localities Scotland (after Wright)		Northeastern Oklahoma	
	No.	*Per cent*	*No.*	*Per cent*
Normal type	771	77.1	272	90.7
Normal type A	40	4.0	1	0.3
Extreme type	115	11.5	18	6.0
Extreme type A	67	6.7	6	2.0
Other types	3	0.3	—	—
Abnormal	3	0.3	3	1.0
Symmetrical	1	0.1	0	0.0
Totals	1,000	100.0	300	100.0
Special type[1]	Not recognized		5	
Special type A[2]	Not recognized		1	
Special type B	Not recognized		4	

[1] Not included in totals above.
[2] Included in totals above.

type" but has also lost contact with r. post. B, figure 6.

Special type, designates forms whose RX is separated from RA.

Special type A, wherein the RA is also separated from r. post. B.

Special type B, includes specimens whose RX is separated from RA and anal X loses contact with post. B.

The loss of contact between RX and RA is second in frequency of occurrence only to the modification effected by contact between RA and 1. post. R.

DEVELOPMENTAL TRENDS

There appear to be three major trends of development in the *post.* IR of Upper Paleozoic Inadunata. The first and most important involves the elimination of RX from the dorsal cup and the early resorption of RA which leaves anal X the only anal element in the calyx. This is termed "Developmental Trend A" and is illustrated with specimens of *Phanocrinus calyx* (McCoy) after Wright, text-figs. 1, 2 and 3. Considering only the appearance of the calyx in side view, figure 3 could easily be mistaken for a Pennsylvanian delocrinid.

RX is also eliminated from the cup but RA continues to be a very prominent calyx element in the second trend. This is designated "Developmental Trend B" and is illustrated by a specimen of *Phanocrinus calyx* after Wright, text-figure 4. Also a sketch of *Ethelocrinus plattsburgensis* Strimple (1938)[3] is given as text-figure 5 to show an actual species with this type of *post.* IR but of course no actual relationship between these species is suggested. There is some evidence that RA is later resorbed in this trend. In the Cromyocrinidae a similar arrangement in the *post.* IR occurs in *Ulocrinus sangamonensis* (Meek and Worthen). Also in the specimen figured by Wright and Strimple (1945) as *Ulocrinus buttsi* Miller and Gurley the resorption of RA is indicated but in the holotype of this species as originally figured by Miller and Gurley (1890) the RA is dominant and anal X has become an insignificant element barely retained in the cup. Sketches of these specimens are presented in the paper on "*Mooreocrinus* and *Ureocrinus*, etc." by Wright and Strimple (1945, p. 223, text-figures 1, 3 and 4).

"Developmental Trend C" is illustrated by text-figures 6, 7 and 8, the first two being variations of *P. calyx* after Wright and the last *Aesiocrinus osagensis* (Strimple) of the Ampelocrinidae, illustrating the one anal (RA) plate stage. In this trend RA moves to a direct posterior position with anal X and RX above and gradually these two elements are pushed out of the dorsal cup.

Dr. Bather (1918) was an ardent exponent of the idea that the RA may be resorbed. He believed, however, that this plate was produced by division of the r. post. R and because it originated as a calyx element, rather than from the anal tube, he contended that it could never pass up out of the cup. Although he argued his case well it is possible that he might have changed his views if he had understood the Ampelocrinidae and the evidence furnished by studies of variations in anal structures. It is certain that RA is resorbed in many forms but the movement of RA to a dominant posterior position, where it may become the only remaining anal element, cannot be denied. Kirk, (1944, p. 234), in his consideration of the genus *Cymbiocrinus*, recognized that the single anal element is probably not anal X although " . . . we may so denomin-

[3] This species is placed under *Parulocrinus* by Moore and Plummer (1940) and by Bassler (1943) but specimens with the arms preserved are now in my collection and the species is a representative of *Ethelocrinus* as defined at this date.

EXPLANATION OF PLATE 77

All figures unretouched photographs enlarged 2.5 diameters unless otherwise noted.

FIGS. *1–6—Phanocrinus alexanderi* Strimple, n. sp. *1*, side view, *2*, posterior view, paratype No. F 38. *3*, side view from r. ant. radius, *4*, *post.* IR to the right, paratype No. F 36. *5*, posterior view, *6*, basal view enlarged 3 diam. Holotype No. F 33, Fayetteville formation (Chester), Oklahoma. (p. 493)

7—Phanocrinus cylindricus (Miller and Gurley), dorsal cup and part of arms viewed from *post.* IR, Fayetteville formation (Chester), Oklahoma. (p. 491)

1

3

4

2

7

6

5

Strimple, *Phanocrinus*

ate it (as anal X) for convenience." In a more primitive genus of this same family, *Ampelocrinus mundus* Kirk shows the anal plate (RA) in contact with r. post. B which strengthens the probability of its infraradial origin. Where it is reasonably certain that an element of the calyx is the radianal it should be given its proper designation, even if it has a position otherwise occupied by anal X as is probable in *Aesiocrinus osagensis.*

DESCRIPTION OF SPECIES

Genus PHANOCRINUS Kirk

PHANOCRINUS ALEXANDERI
Strimple, n. sp.
Plate 77, figures 1–6

Crown approximately 30 mm. long, slightly constricted above the primibrachs. Dorsal cup broad and low, height about 3.8 mm., maximum width 12.6 mm. IBB confined to the small, sharp basal invagination, almost entirely covered by the proximal columnal. Five medium-size BB are slightly tumid, with lower extremities curved and entering the basal cavity, and in side view about one-fourth of their length visible. RR five, pentagonal, not quite twice as wide as long. *Post.* IR slightly depressed, anal elements rather narrow but follow the "Normal type" arrangement.

Ten relatively stout, uniserial arms with well rounded outer surfaces, PBrBr a little more than twice as wide as high, SBrBr slightly wedge shaped, arms not tapering until the uppermost extremities are approached.

Only three known species might be confused with *P. alexanderi;* they are *P. parvaramus* Sutton and Winkler, *P. nitidus* (Miller and Gurley) and *P. cooksoni* Laudon. The first has quadrangular brachials and the arms taper strongly at two-thirds of their length. *P. nitidus* has more strongly wedge shaped brachials and the calyx is considerably higher. *P. cooksoni* has a broad, full dorsal cup but the sides are more erect and the outline is different in side view; its brachials are more regular and thinner than in *P. alexanderi.*

Paratypes of *P. alexanderi* do not have as wedge-shaped brachials as the holotype but their arms are stout and untapered until near the uppermost extremities.

Occurrence.—Fayetteville formation, Upper Mississippian; six miles WSW of Afton, Craig County, Oklahoma.

Types.—Holotype and paratype Nos. F 33 and F 36 to be deposited in the U. S. National Museum.

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NEW TERTIARY BRACHIOPODA FROM JAPAN

KOTORA HATAI
Tôhoku Imperial University, Sendai, Japan

ABSTRACT—The following are described as new, *Terebratulina zinboi, Gryphus kurotakiensis, Diestothyris karafutoensis, Kurakithyris quantoensis, Kamoica (?) chibaensis, Nipponithyris tayaensis, Nipponithyris s-nisiyamai, Isumithyris kazusaensis, Yabeithyris notoensis, Yabeithyris kanazawaensis.* Of the genera, *Kurakithyris, Isumithyris* and *Yabeithyris* are new; the first is referred to the new subfamily *Kurakithyrinae*, the second to *Nipponithyrinae* and the third to the *Laqueininae*. Other unstudied material will probably result in the discovery of more new species.

INTRODUCTION

AMONG the specimens of Tertiary brachiopods, chiefly from Miocene formations at various localities, a number of new species and genera were recognized early in 1941, but owing to conditions prevailing since the latter part of that year, publication of them has been delayed.

The brachiopod fauna of Japan is not well known, a partial study of this group was published by the writer in an article entitled "The Cenozoic Brachiopoda of Japan," which appeared in "Science Reports of the Tôhoku Imperial University, Second Series, Geology, Volume 20, 1940." Since then many specimens have accumulated from various sources and the writer takes this opportunity to make public the results of the first of his studies on them.

ACKNOWLEDGEMENTS

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DESCRIPTIONS OF NEW GENERA AND SPECIES

TEREBRATULINA ZINBOI Hatai, n. sp.
Plate 78, figures 1–4

Description.—Shell small, measuring about 10.0 mm. in length, 9.0 mm. in width and 4.0 mm. in thickness of intact valves; suborbicular, anterior margin broadly rounded, biconvex rectimarginate, anterior and lateral commissures straight; dorsal umbo somewhat swollen, hinge-line short, angulate; beak not swollen, short, obliquely truncated by an incomplete foramen, subcircular in shape; deltidial plates disjunct, widely separated; test thick, heavy, punctate, punctations of branching pattern; surface sculpture consisting of radial riblets, which increase in number anteriorly by bifurcation and interpolation, about 4 per 2 mm. at anterior margin, rather raised, round on top, much wider than interspaces which are narrow, deep and round-bottomed; radials more or less granulated at crossing of concentric lines; interior inaccessible.

Type locality.—Three kilometers east of Ginzan-batake, Tamano-Mura, Kita-Murayama-Gun, Yamagata-Ken. Ginzan formation. Miocene.

Depository.—G.I.S. Coll., Reg. No. 72530.[1]

Remarks.—*Terebratulina reevei* Dall (1920)[2] from the Philippine Islands may be a similar species, but the aspect of the dorsal umbo and details of the radial sculpture distinguish the present species from it. The compressed valves, swollen dorsal umbo and narrow round-bottomed interspaces between the raised riblets are all features which distinguish *T. zinboi* from other known members of the genus in Japan.

[1] G.I.S. Coll. indicates specimens deposited in the collection of the Institute of Geology and Palaeontology, Tôhoku University, Sendai, Japan.

[2] A specimen has been sent to the writer for comparison. It is from St. 5398, 114 fathoms, northwest of Leyte, Philippine Islands, U. S. Nat. Mus. cat. no. 298312.

GRYPHUS KUROTAKIENSIS Hatai, n. sp.
Plate 78, figures 12, 13, 18

Description.—Shell small, measuring about 12.5 mm. in length, 10.5 mm. in width and 7.5 mm. in thickness of intact valves; subquadrate, anterior margin squarely rounded, lateral margins subparallel, lateral commissure sharply curved dorsally in region just anterior to middle of shell, anterior commissure sulciplicate, the fold not very strong; valves nearly equally convex, both swollen, especially in region posterior to middle of shell; surface with fine concentric growth lines which are periodically strong and apparently foliated; beak region swollen, beak rather small and pointed, incurved towards dorsal valve, pierced by a small circular foramen, which is complete, symphytium solid, provided with rather prominent mesial ridge; test apparently rather thin, punctations minute, elongate in shape and rather sparsely scattered over surface; interior features inaccessible.

Type locality.—Kurotaki, Oriki-Zawa, Kameyama-Mura, Kimitsu-Gun, Chiba-Ken. Kurotaki formation. Miocene.

Depository.—G.I.S. Coll., Reg. No. 28276.

Remarks.—The generic position of the present species was determined only by the external features, such as the type of folding and characters of the beak. Among the species of *Gryphus* from Japan, there is none for which the present one can be mistaken.

DIESTOTHYRIS KARAFUTOENSIS
Hatai, n. sp.
Plate 78, figures 9–11

Description—Shell small, measuring about 10.0 mm. in length, 9.5 mm. in width and 3.8 mm. in thickness of intact valves; roundly elongate, anterior margin broadly rounded, anterior and lateral commissures straight; valves nearly equally convex; surface with fine concentric growth lines, some rather strong, crowded on both anterior and lateral sides of shell; test thin, rather densely punctate, punctations rather elongated and small; beak prominent, high, pointed, subrhynchonellid in its curvature dorsally, deltidial plates widely disjunct, foramen incomplete more or less quadrate in shape pedicle-collar not visible; dorsal umbo small and pointed, hinge-line long, only slightly arched; interior inaccessible.

Type locality.—Third tributary of the Suisha River, Kosato, Rutaka-Machi, Rutaka-Gun, South Saghalin. Probably Pliocene.

Depository.—G.I.S. Coll., Reg. No. 72531.

Remarks.—Although the interior features of this shell are inaccessible owing to the fragile nature of the test the characters of the beak and foramen, seem to ally it with *Diestothyris*. In the lack of sulcate folding, the possession of a sub-rhynchonelliform beak and the fragile nature of the test, this species may prove to represent a new genus. There appear to be no known species of Brachiopoda from Japan with which the present one can be confused.

Subfamily KURAKITHYRINAE
Hatai, n. subfam.

Definition.—Brachiopods possessing an indistinct cardinal process in the adult, which develops from a very weak one in the young and possessing ventrally recessive dental plates in the adult which develop from what appear as swollen bases in the young; pedicle collar obsolete in both young and adult; cardinalia divided into inner and outer hinge plates, the former appearing as a deep trough and bordered by the latter which appear as swollen crural bases, the whole excavated beneath and supported by the prominent median septum in both young and adult; descending branches attached to median septum by very short connecting bands in young, but becoming free in adult; folding rectimarginate to sulcate.

Remarks.—The definitions of the subfamilies *Dallininae* and *Frenulininae* of the *Dallinidae* and the *Laqueininae* and *Pictothyrinae* of the *Laquidae* do not include brachiopods possessing characters of the new genus *Kurakithyris*.

Genus KURAKITHYRIS Hatai, n. gen.

Genotype.—*Kurakithyris quantoensis*, n. gen. n. sp.

Diagnosis.—Shell biconvex, rectimarginate to sulcate, foramen complete, small, subcircular, permesothyrid (?), deltidial plates conjunct, mesial ridge low; hinge line short, hinge-teeth not strong, supported by ventrally recessive dental plates in adult and by apparent swollen bases in young; no median ridge in ventral valve; muscular im-

pressions in both valves indistinct; pedicle collar indistinct; cardinalia very weak in young, indistinct in adult, divided into inner and outer hinge-plates by swollen bases of crural processes, inner hinge-plates trough-like, supported by a prominent median septum, excavated beneath; median septum abruptly descending anteriorly; descending branches attached to median septum by short connecting bands in young which become free in adult; test not thick, finely punctate, punctations minute, suboval in outline.

Remarks.—This interesting genus is distinguishable from *Campages* Hedley (Thomson 1927), by the permesothyrid (?) foramen, possession of ventrally recessive dental plates, small and circular foramen, indistinct cardinal process and pedicle collar. From *Japanithyris* Thomson (1927), the present genus is distinguished by the possession of dental-plates and in the characters of the beak. *Dallina* Beecher (Hatai 1940), is also separable from the present genus by the characters of the beak and dental plates as well as by the cardinal process.

Kurakithyris quantoensis Hatai, n. sp.
Plate 78, figures 24–26

Description.—Shell of moderate size, measuring about 22.5 mm. in length, 13.0 mm. in width and 17.5 mm. in thickness of intact valves; elongate subquadrate in outline, rather convex, ventral valve deeper than dorsal; test not thick, densely and finely punctate, punctations minute, suboval in shape; anterior commissure weakly sulcate, lateral commissure nearly straight; hinge-line short, rather sharply arcuate, curving up under the conjunct deltidial plates which are provided with a low mesial ridge; beak not swollen, foramen complete, small, subcircular, permesothyrid (?), surface with concentric growth lines which are crowded on anterior and lateral sides of shell, variably strong, appearing to be foliated locally; hinge teeth not strong, supported by ventrally recessive dental plates separated from shell-wall by a narrow cavity; no mesial ridge observed on floor of ventral valve; pedicle collar or thickened area obsolete; muscular impressions of both valves indistinct; dorsal valve with cardinalia divided into inner and outer hinge plates by crural bases, the whole resting on a median septum and excavated beneath; median septum high, narrow, abruptly descending anteriorly near middle of shell; attachment for connecting bands from median septum to descending branches not observed; cardinal process or shelf-like process over umbo not observed.

Type locality.—Sea-cliff immediately northeast of Koshiba, Kanasawa-Mura, Kuraki-Gun, Kanagawa-Ken. Koshiba formation. Pliocene.

Depository.—G.I.S. Coll., Reg. No. 15436.

Remarks.—This new species is represented by only a single specimen which exhibits its interior features. The loop in the adult is free from the median septum as in *Dallina*. In the absence of any outstanding cardinal process or shelf-like process over the umbo, this species can be referred to no known genus of the *Dallinidae*. This view is also supported by the presence of dental plates of the hinge teeth. The crowding of the growth lines and foliation of the concentric sculpture seem to suggest the maturity of the present specimen

In the presence of dental plates, absence of any outstanding cardinal process, indistinct pedicle collar and very weak muscu-

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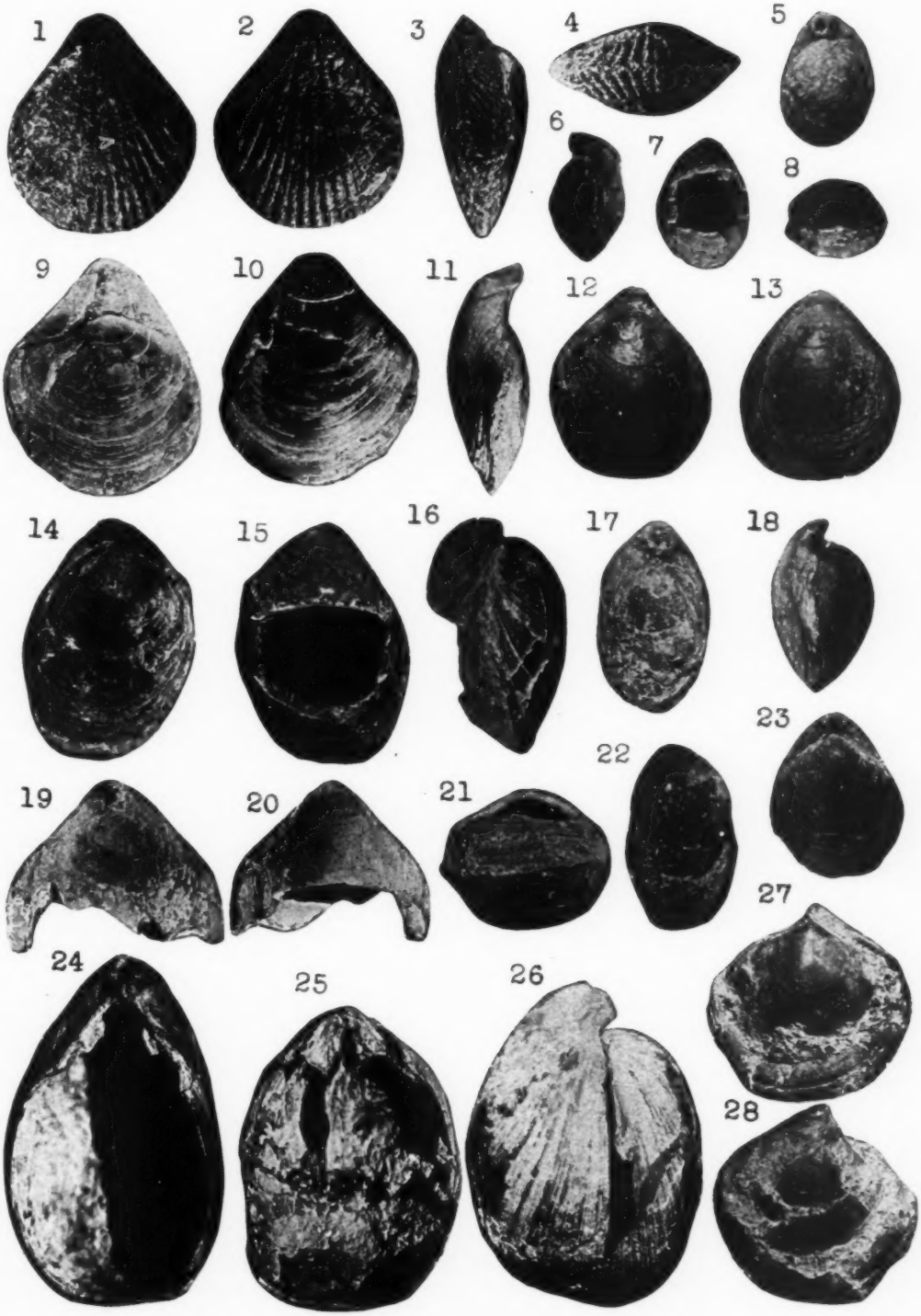
Explanation of Plate 78

(All figures are ×2.)

Figs. *1–4—Terebratulina zinboi* Hatai, n. sp. (p. 494)
5–8—Isumithyris kazusaensis Hatai, n. gen., n. sp. (p. 498)
9–11—Diestothyris karafutoensis Hatai, n. sp. (p. 495)
12, 13, 18—Gryphus kurokiensis Hatai, n. sp. (p. 495)
14, 16, 21—Yabeithyris notoensis Hatai, n. gen. n. sp. (p. 499)
17, 22—Nipponithyris s-nisiyamai Hatai, n. sp. (p. 497)
19, 20—Kamoica (?) chibaensis Hatai, n. sp. (p. 497)
23—Yabeithyris kanazawaensis Hatai, n. sp. (p. 499)
24–26—Kurakithyris quantoensis Hatai, n. gen. n. sp. (p. 496)
27, 28—Nipponithyris tayaensis Hatai, n. sp. (p. 497)



Hatai, Japanese Tertiary Brachiopods

lar impressions, it is difficult to place this species or its genus in any of the subfamilies of the *Dallinidae*, and the characters of the cardinalia remove this genus from the subfamilies of the *Laqueidae*. There is no known species from Japan with which the present one can be confused.

Terebratella nipponiensis Yokoyama (1910),[3] from the same locality as *Kurakithyris quantoensis*, is here referred to the genus *Kurakithyris*.

KAMOICA (?) CHIBAENSIS Hatai, n. sp.
Plate 78, figures 19, 20

Description.—Shell suborbicular, measuring about 17.0 mm. in length, 15.0 mm. in width and 7.5 mm. in depth of intact valves; biconvex rectimarginate, the ventral nearly twice the dorsal in convexity; anterior and lateral margins evenly rounded, hinge line broadly arcuate; beak moderately swollen, suberect, foramen moderate, circular, permesothyrid, deltidial plates conjunct; test rather thin, punctate, punctations minute, oval, densely scattered over surface, sculpture consisting of fine concentric growth lines; hinge-teeth supported by ventrally recessive dental-plates which leave between them and shell wall a narrow cavity; ventral muscular impressions obscure, no medial ridge on floor of ventral valve; pedicle-collar indistinct; cardinalia divergent clear to apex, there headed by a small transverse cardinal process; median septum low, extending posteriorly to cardinal process, anteriorly reaching to near middle of valve; attachment for connecting bands from descending branches to median septum not observed; dorsal muscular impressions obscure; crural bases somewhat vertical in position.

Type locality.—Northern valley of Higashi-Owada, Kimitsu-Gun, Chiba-Ken. Neogene.

Depository.—G.I.S. Coll., Reg. No. 72533.

Remarks.—The present new species is separable from *Kamoica iduensis* Hatai (1936) by the more oval outline, less developed median septum, weaker cardinalia and less prominent cardinal process.

[3] The original specimen was examined by the writer; it is preserved in the Geological Institute, Tokyo Imperial University.

NIPPONITHYRIS TAYAENSIS Hatai, n. sp.
Plate 78, figures 27, 28

Description.—Shell small, measuring about 12.5 mm. in length, 7.5 mm. in width and 6.0 mm. in depth of intact valves; narrowly elongate, anterior margin rather sharply and roundly pointed; anterior commissure nearly rectimarginate or incipiently uniplicate, lateral commissure curved ventrally, somewhat flexuous near anterior extremity; valves unequally convex, the ventral nearly twice the dorsal in depth, maximum convexity slightly posterior to middle; test thick, punctate, punctations minute, round and rather sparsely distributed; surface with concentric growth lines crowded at sides and nearly obsolete over surface, except for several which appear as raised or corrugated lines near middle part of ventral valve; dorsal umbo, small, pointed, rather swollen; ventral posterior extremity or part just posterior to beak swollen; beak prominent, nipponithyrid, pierced by a circular but complete foramen, beak-ridges rather strong, symphytium solid, its middle slightly raised.

Type locality.—River cliff north of Taya, Iwami-Sannai-Mura, Kawabe-Gun, Akita-Ken. Taya formation. Mio-Pliocene.

Depository.—G.I.S. Coll., Reg. No. 72534.

Remarks.—Although the interior features of this small shell could not be studied owing to the lack of specimens, its generic position was determined chiefly by its affinity with known genera. Among the known species from Japan, *Nipponithyris notoensis* Hatai (1940) is close, but the narrower outline, more unequally convex valves and much stronger surface sculpture serve to separate this species from *N. notoensis*.

NIPPONITHYRIS (?) S-NISIYAMAI Hatai, n. sp.
Plate 78, figures 17, 22

Description.—Shell small, measuring about 12.5 mm. in length, 10.0 mm. in width and 6.0 mm. in depth of intact valves; rotundly elongate, anterior margin rather broadly rounded; anterior commissure rectimarginate, lateral one nearly straight; valves nearly equally convex, although the ventral is slightly deeper, maximum convexity slightly posterior to middle; test thick, punctate, punctations round and rather

sparsely distributed over surface, minute; surface with obsolete growth lines; dorsal umbo small, pointed, more or less swollen; beak rather prominent, pierced by a circular complete foramen, beak-ridges rather strong symphytium solid, nipponithyrid.

Type locality.—River cliff north of Taya, Iwami-Sanni-Mura, Kawabe-Gun, Akita-Ken. Taya formation. Mio-Pliocene.

Depository.—G.I.S. Coll., Reg. No. 72535.

Remarks.—This species can be separated from *Nipponithyris notoensis* Hatai by the lesser convexity of the valves and by the features of the beak.

Genus ISUMITHYRIS Haitai, n. gen.

Genotype.—*Isumithyris kazusaensis*, n. gen. n. sp.

Type locality.—North of Unobe, Oikawa-Mura, Isumi-Gun, Chiba-Ken. Kiwada formation. Pliocene.

Diagnosis.—Shell smaller than that of *Nipponithyris* (Hatai 1940) and *Miyakothyris* (Hatai 1938), biconvex, intraplicate; foramen complete, small, circular, symphytium small, very concave, without any outstanding mesial ridge; hinge-line short, gently arcuate; ventral valve without strong median ridge; cardinalia as in *Nipponithyris*.

Remarks.—The present genus possesses cardinalia identical with that of *Nipponithyris*, but the curvature of the beak is stronger and the folding is intraplicate instead of sulcate. *Miyakothyris* differs from the present genus in having a straighter beak, rectimarginate folding of the valves, much heavier test and much stronger cardinalia. There seems to be no other genus for which the present one could be mistaken.

ISUMITHYRIS KAZUSAENSIS
Hatai, n. gen. n. sp.
Plate 78, figures 5–8

Description.—Shell small, measuring about 7.0 mm. in length, 5.0 mm. in width and 4.0 mm. in depth of intact valves; roundly oval, anterior margin rather narrowly rounded, lateral sides gently and broadly produced; valves unequally convex, the dorsal somewhat deeper than ventral, maximum convexity near middle of shell; test not thick, punctate, punctations fine and rather densely scattered over surface, surface with concentric growth lines which appear foliated periodically on anterior half of shell; hinge-line broadly arcuate; beak small, erect, foramen, mesothyrid, small, circular, complete; symphytium small, very concave, without any outstanding mesial ridge; folding intraplicate, but not strongly so; cardinalia as in *Nipponithyris*, except for not having any septal ridge on floor of ventral valve.

Type locality.—North of Unobe, Oikawa-Mura, Isumi-Gun, Chiba-Ken. Kiwada formation. Pliocene.

Depository.—G.I.S. Coll., Reg. No. 25679.

Remarks.—The present species is separable from *Nipponithyris nipponensis* Yabe and Hatai (1934) by the intraplicate folding of the valves, smaller and much more swollen shell, more incurved beak, shorter symphytium and mesothyrid position of the foramen.

Genus YABEITHYRIS Hatai, n. gen.
Genotype.—*Yabeithyris notoensis*, n. sp.

Type locality.—Hôrakuji, Noto Peninsula, Ishikawa-Ken. Nanao formation (?). Miocene (?).

Diagnosis.—Shell elongate subquadrate, biconvex, rectimarginate; test smooth with concentric growth lines only, rather thick, punctate, punctations minute, elongate-oval, dense; beak short, erect, pierced by a complete foramen, symphytium short, solid, provided with a raised mesial ridge; ventral valve with hinge-teeth supported by ventrally recessive dental plates, muscular impressions obsolete; dorsal valve with cardinalia provided with deep trough posteriorly, anteriorly margined by divergent crural bases and prominent median septum, the latter headed posteriorly by anterior wall of trough; muscular impressions indistinct; no cardinal process, only a small shelf-like process or striated area at posterior part of trough; pedicle-collar indistinct.

Remarks.—The present genus possesses cardinalia recalling the genera *Nipponithyris*, *Pictothyris* and in part also *Laqueus* (Hatai 1940). From *Nipponithyris* the present genus is distinguished by lacking a cardinal process. It, however, recalls strongly the combined characters of *Nipponithyris* and *Pictothyris*, but lacks a cardinal process

so typical of those genera. *Laqueus* is separated from the present genus by the characters of the beak and in not possessing a deep trough.

YABEITHYRIS NOTOENSIS
Hatai, n. gen. n. sp.
Plate 78, figures 14–16, 21

Description.—Shell elongate subquadrate in outline, measuring about 17.5 mm. in length, 12.5 mm. in width and 10 mm. in depth of intact valves; anterior margin squarely rounded, both anterior and lateral commissures straight; test rather thick, densely punctate, punctations minute, elongate-oval; valves nearly equally convex, the dorsal slightly more convex than ventral, maximum convexity posterior to middle of shell; beak short, erect, pierced by a complete foramen of small size; symphytium solid, short, with a short raised mesial ridge; dorsal hinge-line rather sharply arcuate; surface with concentric growth lines, which are crowded on both anterior and lateral margins of shell, mostly obsolete over surface but some appear foliated; ventral valve with hinge teeth supported by ventrally recessive dental plates, which leave between them and shell wall a narrow cavity; ventral and dorsal muscular impressions obsolete; dorsal valve with cardinalia provided with deep trough posteriorly and there headed by a small striated area or shelf-like process, anteriorly margined by divergent crural bases between which a prominent median septum is inserted; crural bases oblique as in *Pictothyris*, and stout; median septum rather strong, highest at point of union with connecting bands from descending branches to septum, posteriorly concave, anteriorly abruptly descending to floor of valve; pedicle collar indistinct.

Type locality.—Hôrakuji, Noto Peninsula, Ishikawa-Ken. Nanao formation (?). Miocene (?).

Depository.—G.I.S. Coll., Reg. No. 72536.

Remarks.—This genus in the character of its cardinalia resembles *Nipponithyris* in having a deep trough but lacks a cardinal process; in its crural bases it is close to *Pictothyris* but has a deep trough and no cardinal process. The cardinalia is also similar to that of *Laqueus* but the type of median septum as well as the crural bases are different and the characters of the beak are also different.

YABEITHYRIS KANAZAWAENSIS
Hatai, n. sp.
Plate 78, figure 23

Description.—Shell not large, measuring about 13.0 mm. in length, 13.0 mm. in width and 6.0 mm. in depth of intact valves; suborbicular, biconvex, rectimarginate, lateral commissure straight; dorsal hinge-line gently arcuate, anterior and lateral margins rounded; valves nearly equally convex; surface with concentric growth lines which corrugate anterior margin and are crowded on lateral sides of shell, elsewhere obscure; test rather thick, punctate, punctations minute, rather densely distributed over surface; beak small, pointed, pierced by a circular complete foramen, symphytium solid, provided with a mesial ridge; interior features inaccessible, but dorsal valve provided with prominent median septum as can be seen from external surface.

Type locality.—Hôrakuji, Noto Peninsula, Ishikawa-Ken. Nanao formation. (?). Miocene (?).

Depository.—G.I.S. Coll., Reg. No. 72537.

Remarks.—The present species is distinguishable from the genotype by the more circular outline of the shell and compressed nature of the valves.

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JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 4, pp. 500–508, 4 TEXT FIGS., JULY 1948

THE FORAMINIFER *ORBULINA UNIVERSA* D'ORBIGNY, A SUGGESTED MIDDLE TERTIARY TIME INDICATOR

L. W. LEROY
Colorado School of Mines, Golden, Colorado

ABSTRACT—It is suggested that points of lowest stratigraphic occurrence of the pelagic foraminifer *Orbulina universa* d'Orbigny occurring in a continuously deposited, open sea, deep water globigerine facies sequence, fall on or in close proximity to a time horizon within Middle Tertiary sections throughout tropical and subtropical zones of the world. It is recommended that these points constitute a datum to be termed the *Orbulina surface*. The recognition of this surface would assist materially in establishing world-wide Tertiary time-stratigraphic correlations. The distribution and significance of *Orbulina* and its allied form, *Candorbulina*, in the Kassikan section of central Sumatra is discussed. This section is believed to contain a qualified point for the *Orbulina surface* and is recommended as the type for the western portion of the East Indian Archipelago.

INTRODUCTION

RECOGNITION and definition of interregional time surfaces and correlation of time-stratigraphic units have been a challenge to paleontologists and stratigraphers for decades. Classic European Tertiary chronologic terminology has been applied the world over even though workers are aware that sediments and faunas assigned to the "Miocene" of the Caribbean region are not necessarily contemporaneous with those of the "Miocene" of the East Indian region or of the Paris Basin. The question arises: what approach may best be followed to improve and establish more accurate definition of world-wide time units within the Tertiary?

During the past 15 years numerous papers devoted to small and large benthonic Foraminifera have been published and authors have indicated or suggested the correlation of deposits on the basis of microfaunal affinities. A survey of the contributions shows that little attention has been given to the possible correlative time value of the less diversified *pelagic* Foraminifera. It is the writer's conviction that this group of fossils holds the solution for improving and establishing more accurate long range Tertiary correlations. Stainforth (1947) has also emphatically expressed this viewpoint.

Admitting the incompleteness of this paper and realizing the magnitude of repercussion that may result, the writer's purpose is threefold: first, to bring to the attention of micropaleontologists the possible value of the pelagic foraminifer *Orbulina universa* d'Orbigny as an index for defining a world-wide middle Tertiary time surface; second, to place on record the vertical distribution and biostratigraphic significance of the species in the "Miocene" of central Sumatra; and, third, to stimulate more interest and research in application of pelagic Foraminifera to long range correlation problems.

BENTHONIC VERSUS PELAGIC FORAMINIFERA

Benthonic foraminiferal suites in any region vary radically from shallow to deep water with temperature serving as the primary controlling factor. Natland (1933) has adequately demonstrated important changes in Recent bottom-dwelling microfaunas off the coast of Southern California. Similar variations have been noted in the Gulf of Mexico. Shallow water benthonic faunas also assume different aspects as a result of other varying environmental conditions. The writer (1938) has demonstrated the occurrence of such changes in the assemblages of Pepper Bay on the west coast of Java. Hedberg (1937, p. 686) clearly emphasized this fact and stated "environment of deposition is of tremendous importance in controlling the constitution of foraminiferal assemblages. There may be more

similarity between a deep-water upper Oligocene fauna and a deep-water middle Miocene fauna than between shallow- and deep-water faunas of the same age. Age correlation of formations based merely on percentage of like species is exceedingly dangerous and may indicate likeness of facies rather than contemporaneity of deposition." In order to accurately establish contemporaneity of deposits on the basis of the benthonic foraminiferal faunas, knowledge of lateral faunal control is of utmost importance.

Pelagic Foraminifera, represented by fewer genera and species than the benthonic group, are more or less independent of bottom environment. Their distribution, development and dispersal are controlled by the physical and chemical nature of the upper layers of the sea, wind patterns type and intensity of currents and inter-connection of seaways.

Globigerina and *Globigerinoides* are characteristic pelagic types. They are of worldwide distribution in Late Mesozoic. Cenozoic and Recent deposits and in many assemblages their discarded tests constitute a major faunal element. Certain Recent deep sea deposits have been commonly and rightfully designated "*Globigerina ooze.*" *Orbulina* and *Candorbulina*, the two forms considered in this paper, are likewise considered pelagic although it is not improbable that some individuals during late maturity became adjusted to benthonic habitats.

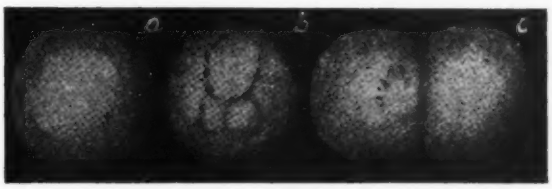

FIG. 1—*a*, *Orbulina universa* d'Orbigny ×35, *b*, *Candorbulina universa* Jedlitschka ×35, *c*, *Candorbulina univresa* Jedlitschka, bilobed variety, ×44. Specimens from *Orbulina-Candorbulina* zone, Kassikan section, central Sumatra.

ORBULINA AND RELATED GENERA

Cushman (1940, p. 290) defined the genus *Orbulina* d'Orbigny as:

> Test in the early stages, like *Globigerina*, later developing a globular chamber entirely enclosing the earlier one which may be later resorbed; wall calcareous, often of several layers, with perforations of various sizes, no general aperture, exterior with fine elongate spine.

This genus ranges from middle Tertiary to Recent. Pre-Tertiary records are now considered fallaceous. *Orbulina universa* (fig. 1a.) is widely distributed in the sediments of present seas and oceans. In middle and late Tertiary deep sea deposits of the East and West Indian regions its tests comprise a conspicuous fraction of microfaunal suites. Laiming[1] states, "the Pacific Coast record indicates abundant *Orbulina* in the Upper Tertiary and Lower Pleistocene, rare occurrence in the Middle Tertiary and questionable or none in the Lower Tertiary." In the Caribbean region, Coryell and Rivero (1940) remarked that the species is one of the dominant forms in the Haitian material from Port-au-Prince deposits of late Middle Miocene age. Cushman and Jarvis (1930) recorded the form in the type Bowden marl (upper Middle Miocene) of Jamaica. Bermudez[2] comments, "with respect to *Orbulina universa* and *Orbulina bilobata*, I can inform you that these species apparently did not exist in formations older than the Middle Oligocene in sections of Cuba and Hispanola, and that the occurrence of the same has been always noted in open, deep sea deposits." According to Coryell and Mossman (1942), *Orbulina* is exceedingly abundant in the Charco Azul (Pliocene) formation of Panama. Nuttall (1932) failed to record it from the Alazan formation (Lower Oligocene) of Mexico. In the Tertiary of Trinidad the lowest occurrence of *Orbulina* is in the Upper Cipero formation (Upper Oligocene) according to Bolli.[3]

Candorbulina Jedlitschka (fig. 1b.), a form allied to *Orbulina* and stratigraphically restricted in the central Sumatran Tertiary, was described by Cushman and Dorsey (1940, p. 41).

[1] B. Laiming, Texas Company, personal communication.

[2] P. S. Bermudez, Creole Petroleum Corp., personal communication.

[3] H. Bolli, Trinidad Leaseholds, Ltd., personal communication.

Test similar to *Orbulina*, but with apertures consisting of one or more rings of small openings coinciding with the edge of contact of the earlier *Globigerina*-like chambers with the adult spherical one.

Commonly associated with *Candorbulina universa* Jedlitschka in the Sumatran section are forms consisting of two nearly equidimensional chambers (fig. 1c.), one of which partially envelops the other. Jedlitschka named this type *Candeina biloba*. Subsequent studies by the writer have revealed this "species" to be a variant of *Candorbulina*, thereby supporting the statement of Cushman and Dorsey, "the *Candeina* species figured by Jedlitschka would be included in the range of variation of *Candorbulina universa*." *Candorbulina universa* is recorded from the Tertiary of Sumatra, New Guinea, Egypt, Austria, Czechoslovakia, Colombia, Trinidad, Venezuela and from the east and gulf coasts of United States. Stainforth[4] states, regarding the lowest occurrence of *Candorbulina* in Ecuador, "I have found in Ecuador that *Candorbulina* appears within the zone marked by extinction of *Globigerina* cf. *concinna* and the slightly higher extinction of *Globigerina dissimilis*. I call this interval upper-Middle Oligocene, and it is my experience that this narrow zone is recognizable in many parts of the Caribbean region." There appears to be no published record of *Caudorbulina* from the Pacific coast of North America.

Candorbulina universa appears to be more or less restricted to the middle Tertiary, therefore, it may possess strategic correlation value. Cushman and Dorsey (1940) wrote, "It would seem that *Candorbulina* originated from *Globigerinoides* in the Miocene, and gave rise to *Orbulina*, but itself becoming extinct. If this be the case, *Candorbulina* should make a good index fossil for the Miocene." In the Kassikan section of central Sumatra both *Candorbulina* and *Orbulina* are introduced simultaneously in approximately equal numbers. The former disappears about two hundred feet higher in the section but *Orbulina* continues into younger beds.

[4] R. M. Stainforth, Tropical Oil Co., personal communication.

ORBULINA IN THE CENTRAL SUMATRAN TERTIARY

Orbulina universa and *Candorbulina universa* possess definite time-stratigraphic significance in deep-water Tertiary ("Miocene") deposits of central (fig. 4) and south Sumatra. Similar importance of these forms has been noted in the Tertiary of New Guinea.

In following a detailed biostratigraphic analysis of *Orbulina* and *Candorbulina* in the Telisa and Lower Palembang formations of central Sumatra, the writer first became aware of the possibility that under proper sedimentational and hydrographical conditions these two genera might serve as control for defining a relatively accurate interregional chronologic datum within the Middle Tertiary. Thus, it was concluded and is herein suggested that *points of lowest stratigraphic occurrence of Orbulina in a continuously deposited, open sea, deep-water globigerine facies sequence, fall on or in close proximity to an equivalent time horizon within Middle Tertiary sections in tropical and subtropical zones of the world.* It is proposed that qualified "points of lowest stratigraphic occurrence" constitute a time datum to be termed the *Orbulina surface*. The selection and placement of these points depend on: (1) favorable type and relationship of biotic facies, (2) non-cessation of sedimentation during the time interval in which the species was first biologically introduced into the geologic column, (3) inter-connection of seas and oceans at time of introduction and (4) rapid dispersal of the species.

Section A (fig. 2) illustrates optimum conditions required for selection of a qualified point. This selection must be governed by detailed areal mapping of the deposits and precisely determined paleontologic and stratigraphic data; otherwise, a non-valid point as shown in Section B may be chosen. Qualified points once having been accurately determined locally, subjacent and superjacent non-*Orbulina* bearing facies equivalents in contiguous areas may then be adjusted into the regional or provincial stratigraphic and chronologic scheme. The *Orbulina surface*, when interregionally established, will probably require modification of age assignments of certain

Tertiary formations and time-stratigraphic units now allocated to several standard European time divisions. Lack of data does not permit placement of the *Orbulina surface* in the western European section; this phase of the problem must await the interest, investigation and cooperative effort of

central Sumatra. The pre-Tertiary and Basal Sandstone series outcrop near the headwaters of Soengei (river) Paimbaran. The lower 2000 feet of the Telisa formation was measured and collections were made along Soengei Poeoh. The upper 870 feet was investigated and correlated in 60-foot

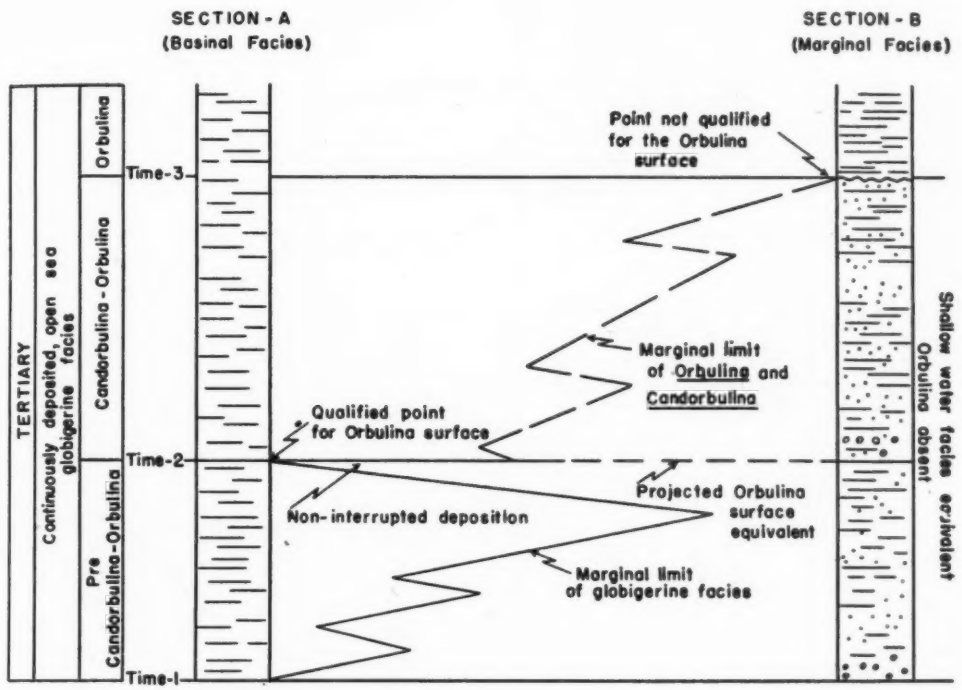

FIG. 2

micropaleontologists and stratigraphers the world over.

The Kassikan section of central Sumatra is recommended as a type sequence containing a qualified control point for the *Orbulina surface* in the western part of the East Indian Archipelago. All requirements for establishing a valid point are believed to be fulfilled by it.

STRATIGRAPHY OF THE KASSIKAN SECTION

The composite Kassikan section (fig. 3) has been constructed on the basis of outcrops, drill holes and auger borings, in the vicinity of Aliantan, Sultanate of Siak, auger holes spaced 160 feet apart along the Kassikan traverse. The nature of the Lower Palembang and the basal portion of the Middle Palembang formations are also known from correlating auger hole sections along the Kassikan traverse. Selection of samples above the Basal Sandstone series at three-foot intervals allowed precise placement of the lowest stratigraphic occurrence of *Orbulina universa* and *Candorbulina universa* and also permitted accurate evaluation of their frequencies and distribution.

The section includes, in ascending order: Pre-Tertiary, Basal Sandstone Series, Telisa, Lower Palembang and Middle Palembang formations. The lithologic and paleontologic

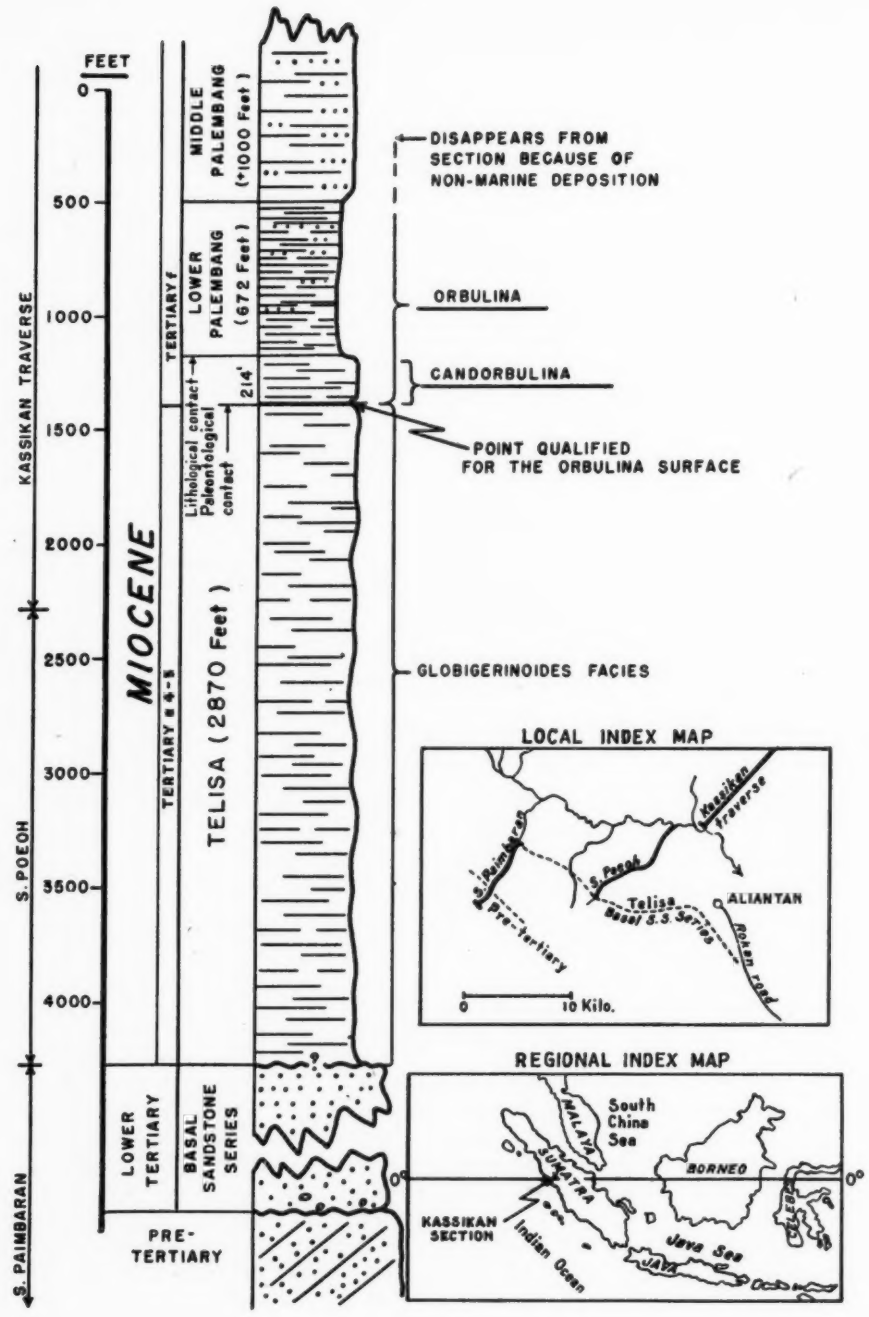
FEET
0
500
1000
1500
2000
2500
3000
3500
4000
KASSIKAN TRAVERSE
S. POEOH
S. PAIMBARAN
MIOCENE
TERTIARY f
TERTIARY e-5
MIDDLE PALEMBANG (+1000 Feet)
LOWER PALEMBANG (672 Feet)
214'
Lithological contact
Paleontological contact
TELISA (2870 Feet)
LOWER TERTIARY
BASAL SANDSTONE SERIES
PRE-TERTIARY
DISAPPEARS FROM SECTION BECAUSE OF NON-MARINE DEPOSITION
ORBULINA
CANDORBULINA
POINT QUALIFIED FOR THE ORBULINA SURFACE
GLOBIGERINOIDES FACIES
LOCAL INDEX MAP
Kassikan traverse
S. Paimbaran
S. Poeoh
Telisa
Basal S.S. Series
Pre-tertiary
ALIANTAN
Roean road
0
10 Kilo.
REGIONAL INDEX MAP
MALAYA
South China Sea
SUMATRA
BORNEO
KASSIKAN SECTION
Indian Ocean
Java Sea
JAVA

FIG. 3

characters of these units are summarized below.

PRE-TERTIARY

Pre-Tertiary strata, outcropping near the headwaters of Soengei Paimbaran, consist mainly of hard, bluish-gray to brown, jointed quartzites and argillites which are discordant below the Basal Sandstone series of probable early Tertiary age.

TERTIARY

Basal Sandstone Series.—Buff to gray, medium to coarse-grained, friable sandstones constitute the main part of the series. Conglomeratic and silty phases are locally developed with the former more prevalent in the lower part. A minimum thickness[5] of 2000 feet was measured by Hofsteenge on Soengei Paimbaran.

The lower boundary is a non-conformity above the pre-Tertiary. The upper boundary is moderately sharp and suggests diastemic relationships.

The age of the Basal Sandstone series is questionable. It is of continental origin and lacks diagnostic fossils. It is tentatively assigned to the Lower Tertiary.

These strata may be traced along the east front of the Barisan Mountains for a considerable distance. Detailed lithologic studies would undoubtedly distinguish several mappable subdivisions.

[5] G. L. Hofsteenge, deceased; geologist, Ned. Pac. Pet. Mij.

Telisa formation.—The Telisa formation as defined lithically consists of 2870 feet of thin-bedded, gray to grayish-brown, foraminiferal shales with occasional thin calcareous interbeds. Finely disseminated carbonaceous material and bluish-gray bentonitic clay laminae occur in the upper portion. Glauconite is locally present. Lithically and faunally the formation remains remarkably constant along the Barisan Mountain front. In the East Coastal Plain area it becomes more arenaceous.

This formation overlies the Basal Sandstone series with apparent conformity but possibly a hiatus exists at this contact. The upper boundary as determined paleontologically lies at the lower limit of *Orbulina universa*. Dufour (1943) defined it thus in South Sumatra. This is believed to be a valid point on the *Orbulina surface*. The lithologic boundary in the Kassikan section occurs 214 feet higher stratigraphically. In the East Coastal Plain area, the Telisa is limited above by an unconformity.

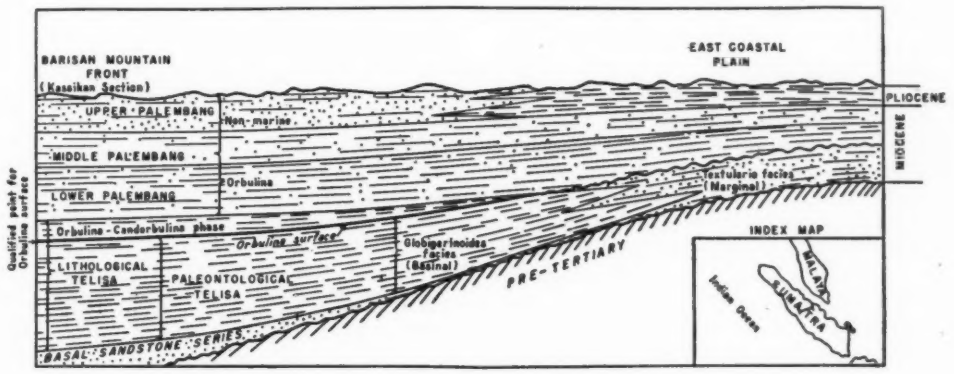

FIG. 4

Two distinct lithological and microfaunal facies are present in the pre-*Orbulina* portion of the Telisa formation in central Sumatra (fig. 4).

1. *Globigerinoides facies:*—This facies is restricted to the lower 2656 feet of the formation in the Kassikan section. It represents a relatively deep, open-sea depositional environment with *Globigerinoides* and *Globigerina* comprising the major components of the microfauna. The *Orbulina-Candorbulina* interval (214 feet thick and lithologi-

cally similar to the Telisa) is excluded on paleontological evidence. Benthonic Foraminifera common to the facies include: *Bolivina sumatrensis, B. gesteri, Bulimina microlongistriata, Cibicides dorsopustulosus, Cibicides tapoengensis, C. koeboeensis, C. soendaensis, C. foxi, Chilostomella oolina, Eponides praecintus, Loxostomum* aff. *L. applinae, Uvigerina sumatrensis, Cancris auriculus, Siphonina indica,* and *Baggina inflata.*

2. *Textularia facies:*—This facies, developed in the East Coastal Plain area is, partly or wholly, an eastward marginal, shallow-water equivalent of the *Globigerinoides* facies. The deposits, consisting of interbedded shales and sandstones, are unconformably overlain by the Lower Palembang and are identified by *Textularia malaccaensis, Elphidium koeboeense, Rotalia umbonata* and *Cibicides soendaensis.* The ostracode fauna is characterized by many species including *Cytherelloidea malayaensis* and *Cytherelloidea nomlandi.*

The Telisa of central and south Sumatra, as paleontologically defined on the basis of large Foraminifera, has been assigned, following East Indian letter terminology, to Tertiary stage e4–5 ("Old Miocene") (Dufour, 1943).

This assignment has been regarded by some workers as a phase of the Aquitanian but the writer makes no assertion as to the authenticity of this correlation.

Lower Palembang.—In the Kassikan section the Lower Palembang formation excluding the *Orbulina-Candorbulina* beds, consists of 672 feet of dark green to greenish-gray, massive to moderately bedded, foraminiferal clay-shale. Minor layers of glauconitic siltstone are of sporadic occurrence throughout. Arenaceous beds become progressively more dominant above. The Lower Palembang-Telisa contact along the mountain front is gradational and its position varies depending on whether the lithologic or paleontologic boundary is preferred. The latter is defined by the lowermost occurrence of *Orbulina universa.* The former occurs 214 feet higher stratigraphically. In the East Coast Plain area the two formations are separated by unconformity. The Lower Palembang-Middle Palembang boundary is typically transitional.

Foraminifera, Ostracoda, otoliths and small mollusca are abundant in Lower Palembang sediments. The microfauna is more diverse than that of the Telisa and even more diverse than Middle Palembang assemblages. Common foraminifers include: *Allomorphina trigonula, Baggina inflata, Bolivina gesteri, B. sumatrensis, B. uniforminata, Cancris auriculus, Cibicides dorsopustulosus, C. koeboeensis, C. foxi, Epistomina elegans, Eponides praecinctus, Globorotalia barrisanensis, Globigerina bulloides, Rotalia sumatrana, Siphonina indica,* and *Uvigerina soendaensis.*

Orbulina universa occurs profusely and persistently throughout the formation. Above the basal lithologic boundary, *Candorbulina* is absent and this horizon probably marks its extinction. Microfaunas of the Lower Palembang reflect shallower water conditions than those of the Telisa.

Dufour considered the base of *Orbulina* to be the Lower Palembang-Telisa contact in South Sumatra and to mark the division between Tertiary e ("Old Miocene") and Tertiary f ("Young Miocene"). The Lower Palembang faunas are definitely older than the *Globorotalia menardii-Sphaeroidinella dehiscens* assemblage which attains widespread distribution in the younger Tertiary of the East Indian Archipelago.

Middle Palembang.—Only the lowermost portion of this formation is considered. These beds are arenaceous greenish claystones, siltstones and fine argillaceous sandstones. Glauconite occurs near the base and carbonaceous material is commonly distributed throughout.

This formation is transitional with the underlying Lower Palembang both lithologically and faunally. It becomes progressively less marine upward and grades into continental claystones and sandstones of the Upper Palembang formation.

The microfauna in the lower part of the formation is similar to that in the upper portion of the Lower Palembang although the number of species is smaller. Foraminifera become exceedingly rare in the middle and upper portions. In contiguous areas, *Operculina, Elphidium, Lepidocyclina* and *Miogypsina* have been noted in restricted numbers. The Middle Palembang is typically a shallow marine to brackish-water

deposit. It is considered young Miocene (Tertiary f) in age.

CONCLUSIONS

1. It is confidently predicted that the much neglected pelagic Foraminifera, when systematically studied, will be found to possess greater value for both regional and provincial Tertiary time-stratigraphic correlation than do the benthonic Foraminifera.

2. The writer is convinced that with adequate and proper stratigraphical and faunal control, *Orbulina universa* and *Candorbulina universa* will permit definition of a time horizon (*Orbulina surface*) within Middle Tertiary sequences throughout tropic and subtropic regions.

3. The Kassikan section of central Sumatra is believed to fulfill all requirements for establishing a qualified point on the *Orbulina surface* and is designated as a type for the western part of the East Indian Archipelago.

4. The establishment of qualified points for the *Orbulina surface* in the West Indies, east and west coasts of United States, Mexico, New Zealand, Australia, Mediterranean province and the eastern part of the East Indian region will be welcomed contributions which will aid in the solution of Tertiary problems.

5. The establishment of points on the *Orbulina surface* inter-regionally and inter-provincially will make possible improved correlation of laterally equivalent non-*Orbulina* bearing sediments containing benthonic assemblages possessing local stratigraphic value.

6. If subsequent data substantiates the existence of a uniform *Orbulina* surface, it may be advisible to reconsider, re-evaluate and modify if necessary, present Middle and Upper Tertiary time assignments with reference to this horizon.

For example, in the Caribbean region and Ecuador *Orbulina* and *Candorbulina* enter the section profusely at the base of the Upper Oligocene though the latter genus extends downward and occurs in a "narrow zone" within the upper Middle Oligocene. The base of this zone, assuming the validity of the *Orbulina* surface as an inter-regional time datum, may correspond to the divisional line marking Tertiary e and Tertiary f of central and south Sumatra. Thus, in terms of West Indian nomenclature, the *Candorbulina* phase of the Kassikan section may be assignable to upper Middle Oligocene, the Lower Palembang to the Upper Oligocene and the Telisa to Middle and perhaps even Lower Oligocene.

7. The writer suggests that careful consideration be given to such pelagic species as *Globigerinoides rubra*, *Globorotalia menardii*, *Pulleniatina obliquiloculata* and *Sphaeroidinella dehiscens* as possible Tertiary time indicators.

8. A systematic survey of the distribution of *Orbulina universa* in modern seas should be made to aid in evaluating the ecologic range of the species during the Middle Tertiary.

9. The writer intends to continue study of the *Orbulina surface*. Comments, suggestions, opinions and criticisms relating to this problem will be welcomed and with permission may be published in a subsequent compilation.

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JOURNAL OF PALEONTOLOGY, VOL. 21, NO. 4, PP. 509–517, 6 TEXT FIGS., JULY 1948

ON *ASTERIGERINA GÜRICHI* (FRANKE) AND REMARKS ON POLYMORPHISM AND THE STRATIGRAPHIC USE OF FORAMINIFERA

J. HOFKER
Brielle, Holland

ABSTRACT—*Asterigerina gürichi* and the two species recognized by ten Dam and Reinhold as *A. staeschei* and *A. frankei* are analyzed statistically as well as in respect to their internal structure. It is shown that these three species are actually one, which has been called *A. gurichi*. The characteristics of the three species according to ten Dam and Reinhold are actually those of the three generations of the species and have no specific significance.

The inner structure shows that the supplementary chambers are separated from the normal ones by a plate with a large opening. The plate seems to be identical with that found in *Epistomina*. The latter's plate is related to similar plates in *Robertinoides* and its allies, as found by Höglund and me.

The genus *Asterigerina* therefore has nothing whatever to do with *Amphistegina*, but is close to *Epistomina*.

Data are given concerning the life cycle of Foraminifera, and it is shown that new species should not be named and used as guide fossils until their bionomics are known from statistical study of as many specimens as can be obtained. Only the study of the inner structure of many specimens, together with bionomic data will give us species with which stratigraphic results without errors may be obtained. Only when all three generations of a species are known should a name be given, if the species is really new. Already established species need detailed study as well.

A SERIES of mostly well preserved specimens of *Asterigerina* was sent me from two drillings, at Maris and at Beeringen respectively, in the Netherlands, by the Dutch Geological Foundation. Over 70 specimens are transparent enough to show the proloculum when observed immersed in rhicinus oil. The prolocula range in diameter from about 6 to about 30μ. A distribution curve (fig. 4) of the megalospheric specimens shows maxima at about 14, 20 and 25μ. I believe that specimens whose prolocula measure about 16μ represent the A_1 generation and that about 25μ is the modal diameter of the A_2-generation. Specimens whose prolocula measure from 6 to 8μ are microspheric or B forms. There is some tendency among these specimens for the size of the test to vary inversely as the diameter of the proloculum. All of the microspheric specimens are large, but several megalospheric specimens attain approximately equal size.

In the last whorl of three well developed microspheric specimens there are 9 or 10 chambers. A single very large megalospheric test has 8 chambers in the last whorl, but most smaller specimens of megalospheric generations show only 5 to 7 chambers.

All megalospheric tests consist of 3 whorls, but microspheric specimens have as many as 5. In microspheric individuals the ventral side is more convex than the dorsal, but the two sides of megalospheric specimens are about equally convex.

The umbilical region of the ventral side is occupied by the so-called supplementary chambers which underlie the primary normal chambers, and by a central homogeneous knob, filling up the rest of the umbilicus. These supplementary chambers have more or less pointed ends extending outward from one-half to two-thirds of the distance toward the periphery of the test, and are rhombic in shape. Their walls are pierced by pores with diameter of about 1½μ, like those of the primary chambers. The number of exposed supplementary chambers is one less than the number of primary chambers in the last whorl and varies from 4 to 9. This is because the last-formed chamber is not accompanied by a corresponding supplementary chamber.

Most tests are furnished with a narrow hyaline peripheral carina which lacks pores.

A correlation exists between the ratio of the widths of the supplementary and corresponding primary chambers and the diam-

eter of the proloculum. Ten Dam and Reinhold have employed variations in this ratio to distinguish species, but the graph, figure 6, shows that the distribution is a fairly random one and consequently a difference in this relationship cannot be a specific character.

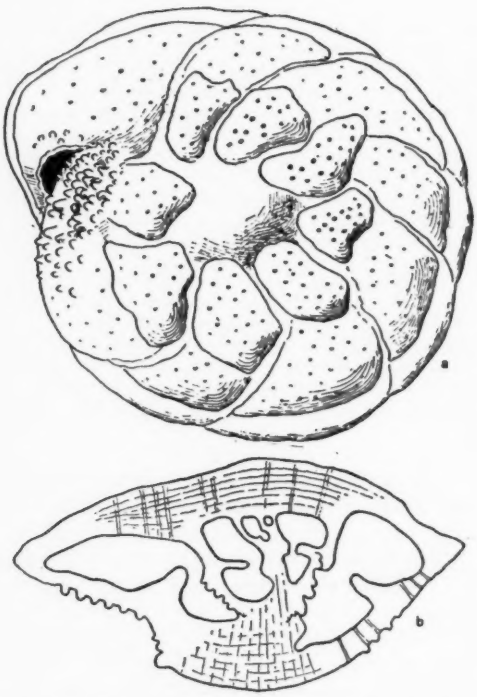

FIG. *1a*—Microspheric specimen of *Asterigerina gürichi*, from the ventral side, ×140. Breadth of secondary chambers equal to free part of normal ones; central chalk-mass; few pustules beneath the aperture. *b:* transverse section through this shell, showing thickness of dorsal wall, large development of the ventral central knob of chalk, normal and supplementary chambers, the latter being ventral sacks from the dorsal ones,with simple walls between succeeding coils, as is shown by the pustules at the inner walls of the supplementary chambers.

The aperture is invariably an arched slit on the ventral side of the last formed primary chamber. Its lip is always somewhat irregular and thickened. Near it the ventral surface is covered with secondary pustules like those occurring on species of *Lamarckina* and *Ceratobulimina*. They also extend onto the marginal part of the adjacent supplementary chamber. Pustules may also occur, but are less abundant, between the aperture and the perifery. Much of the pustulose surface is covered by the next-formed chamber and its supplementary chamber but the pustules may be seen within the transparent chamber walls, indicating that the septal walls are single.

The peripheral edges of the chamber walls at their outer margins are sharp and distinct, and form a variable angle. In specimens from Beeringen this angle averages 40 degrees for megalospheric individuals and 30 degrees for microspheric tests. Megalospheric individuals from Maris have an average angle of 34 degrees. The development of these edges is influenced by the density of the sea water and the difference between the megalospheric tests from these two localities appears to reflect a slight difference in environment and is certainly not a specific difference. The similarity of megalospheric specimens from Maris and microspheric ones from Beeringen emphasizes the necessity for the proper understanding of such differences. No microspheric tests were obtained from Maris where specimens are not abundant.

A striking correlation exists between the amount of secondary test material which fills the umbilicus and the diameter of the proloculum (fig. 5). Similar relations occur in many Foraminifera. Ten Dam and Reinhold, when dealing with similar material, mention this umbilical thickening in their descriptions of Dutch Tertiary *Asterigerina* and describe a central knob in one species and the protruding of sutures in another. The correlation, however, throws new light on this relationship and demonstrates that such differences are not necessarily of specific significance.

I measured prolocula in megalospheric specimens and sketched their central ventral parts. These parts are star-like and the diameter of the center of each star is a very accurate measure of the secondary umbilical deposit. Although there are some variations, these measurements demonstrate that individuals with small prolocula have large umbilical deposits and vice versa (fig. 5).

The interior structure of the tests was studied from transverse and horizontal thin sections and paraffin casts. The dorsal wall,

especially in the microspheric specimens, is thickened by secondary calcareous layers. The dorsal roofs of the chambers form a nearly horizontal plane. The proloculum never is accompanied by a supplementary chamber but subsequent primary chambers are. The supplementary chambers form a ventral part of each normal chamber, separated from it by an obliquely situated lamella pierced in the middle by a wide, somewhat irregular opening. This lamella begins dorsally at the aperture of the former chamber, extends around the inner wall of the chamber, and ends underneath that aperture. It resembles the ridge-like structure of *Epistomina* which can be compared with the tooth-plates in *Ceratobulimina* and in *Lamarckina* (exhaustive studies, which will soon be published, prove that the ridge in *Epistomina* is nothing but an altered tooth-plate). I am convinced, that the laminae or plates separating the dorsal normal chambers of *Asterigerina* from the so-called supplementary chambers are peculiarly formed tooth-plates like those separating the two parts of the chambers in *Robertinoides*, as shown by Höglund (1947).

There are some indications moreover, that the ventral foramina, found up in typical Rotalids, are connected with the irregular opening in the separating plate in *Asterigerina*. In real *Pulvinulina* (not *Eponides*) the chambers are furnished with two apertures, the septal one, connecting them with a former chamber, and the ventral one, connecting them with the umbilical space. When in *Asterigerina* the supplementary chambers are obliterated, this Pulvinuline situation is established. This tooth-plate, widely distributed in the groups of the Virgulinidae, Buliminidae and some other allied groups, thus becomes of high value with respect to the systematic place of several genera. As in *Robertinoides*, no direct connection exist between adjacent supplementary chambers.

In *Amphistegina*, on the contrary, no ventral foramina whatever occur. So *Asterigerina* cannot be allied to *Amphistegina*, as is supposed by most authors. It has to be placed in the group, in which *Bolivina*, *Virgulina*, *Cassidulina* with *Ehrenbergina*, lead to *Cassidulina*, *Ceratobulimina* and *Lamarckina*, and in which *Epistomina* and *Asterigerina* may be links to typical rotaline genera as *Pulvinulina* (not *Eponides*), *Streblus* and *Rotalia*, all genera with more or less narrow pores in their walls, which I will show in another paper dealing with these groups. In *Amphistegina* no supplementary chambers are found.

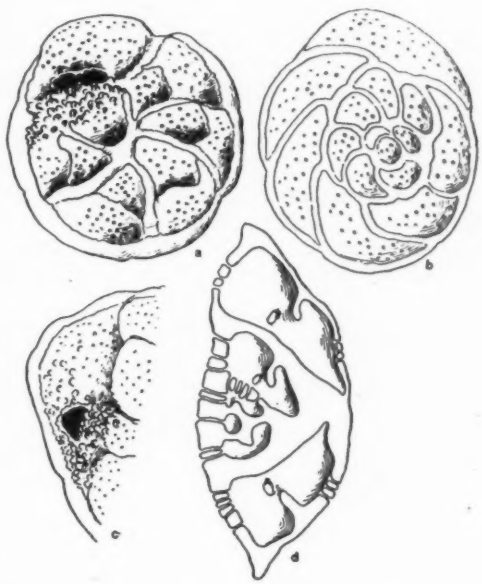

FIG. *2a*—Ventral side of megalospheric specimen of *Asterigerina gürichi* with large proloculum. The aperture shows the ventral and dorsal parts, the former giving rise to the normal foramen with the next chamber, the latter to that with the supplementary one. *b*—dorsal side of megalospheric specimen with large proloculum. *c*—apertural part of such a shell. *d*—transverse section, after a paraffine-preparation showing the connection between normal chambers, and the ventral sack-like outgrowths, called supplementary chambers, and the shape of the pores. The foramina between next chambers are shown too. They are situated close to the connection with the supplementary chambers. All figures enlarged ×140.

Specimens of *Asterigerina* from Beeringen and Maris studied by me indicate that distinction of the three species recognized by Ten Dam and Reinhold in the Dutch Tertiary is very questionable. The differences noted by them are mostly present in my specimens and are characteristic of the different generations or growth forms of a single species which I identify as *A. gürichi*.

I believe that they have mistaken minor variation for specific difference and thereby confused nomenclature.

The characters of the three supposed species recognized by ten Dam and Reinhold may be compared as follows:

A. gürichi	*A. staeschei*	*A. frankei*
Dorsal and ventral sides equally convex.	Ventral side much more convex than dorsal.	Dorsal and ventral sides strongly and equally convex.
Ratio of thickness to diameter *1:2.8*.	Ratio of thickness to diameter *1:1.3*.	Ratio of thickness to diameter *1:2*.
Peripheral keel somewhat rounded.	Peripheral keel sharp but somewhat rounded.	Peripheral keel sharper than in *A. gürichi*, smaller than in *A. staeschei*, somewhat rounded.
2 or 3 whorls visible dorsally.	2 whorls visible dorsally.	2 or 3 whorls visible dorsally.
6 to 9 chambers in last whorl.	6 chambers in last whorl.	6 or 7 chambers in last whorl.
Sutures transparent, not excavated, curving backward.	Sutures more or less distinct, curving backward, *less than in A. gürichi*.	Sutures distinct, transparent, not excavated, curving backward.
Ventral side with *7 to 9 primary*, 6 to 8 supplementary chambers.	Ventral side with 6 primary, 5 or 6 suppl. chambers.	Ventral side with 6 or 7 primary, 6 suppl. chambers.
Suppl. chambers *equally* broad as visible parts of primary chambers.	Suppl. chambers *broader* than visible parts of primary chambers.	Suppl. chambers somewhat broader than visible parts of primary chambers.
Older tests sometimes with projecting umbilical knobs		
Test hyaline, finely perforate.	Test *very rough*, finely perforate.	Test hyaline, finely perforate.
Aperture a curved slit surrounded by fine papaillae.	Aperture a curved slit surrounded by papillae *often covering more than 1/3 of surface.*	Aperture a curved slit surrounded by fine papillae.
Diameter 0.50 mm.	Diamter 0.35 mm.	Diameter 0.40 mm.

The characters of these forms are nearly identical and much uncertainty arises when one tries to identify a specimen as one or another of them. I believe that specimens described as *A. gürichi* by ten Dam and Reinhold are mostly microspheric individuals and there is no doubt that the test illustrated by them in plate 2 figure 1 is microspheric. Some of my specimens intermediate between these and their figure 3 of the same plate occur, however. I consider the latter to be representative of generation A_1. On the next page is shown a comparison of the three generations as represented by typical specimens.

These comparisons and statistical analysis show that the three generations of *A. gürichi* are similar in some respects and different in others from the species recognized by ten Dam and Reinhold. However, I am forced to conclude that in a general way the three species of ten Dam and Reinhold are the three forms of a single species that should be known as *A. gürichi*. It is different from the Recent species, *A. carinata* D'Orbigny, as a statistical study of the latter species has shown me, and as the pores of the latter are much finer than those of *A. gürichi*. Some of the characters that do not exactly correspond in the foregoing comparisons are probably facies differences and none of them appears to be of enough importance to justify separate specific recognition. Certainly all of the differences noted in the three species of ten Dam and Reinhold (given in italics) are represented in one combination or another in the three forms of the single species.

Ten Dam and Reinhold record *A. gürichi* from the upper Oligocene and the upper part of the Middle Oligocene, *A. staeschei* from the Middle and Lower Miocene, and *A. frankei* from the Middle Oligocene and Middle Miocene. The stratigraphic ranges of the first two species are not known to overlap, but both fall within the time range of the third. In this connection the fact should be emphasized that samples of sediments often contain representatives of only a single generation of a foraminifer. This leads me

to a more exhaustive discussion about some subjects in connection with polymorphism and stratigraphic use of Foraminifera. *Asterigerina gürichi* with its somewhat variable generations cannot be considered a useful guide fossil for zonation of the Tertiary of the Netherlands.

At present Foraminifera are more commonly used for zonation and correlation of Tertiary deposits than molluscs that formerly were principally relied upon for this purpose. Especially smaller species of Foraminifera are now used for this purpose. The dead shells of both Foraminifera and Mollusca are used, but the two groups of animals are so fundamentally different in their methods of reproduction that faulty results are likely to be obtained if this matter is not taken into consideration. Molluscs reproduce sexually but do not possess different male and female forms, and they do not have the alternation of generations that is characteristic of many Foraminifera, as I have shown in previous papers and as I will show in yet more detailed studies to come soon.

The A_2-generation of Foraminifera, which produces zoospores after fragmentation of the nucleus as shown by Myers and myself, may be sexed and possibly the two sexes possess recognizable morphological differences. Some evidence pointing in this direction exists in the almost invariable association of two closely related species in some genera e.g. *Globorotalia menardi* and *G. tumida*, though I stated in a study, which will be published, that they may be two generations, which contradicts the ideas on the subject of Cosijn (1938, p. 40).

Form B	*Form A_2*	*Form A_1*
Ventral side equal or more convex than dorsal.	Ventral side generally more convex than dorsal.	Dorsal and ventral sides equally convex.
Ratio of thickness to diameter 1:2.	Ratio of thickness to diameter 1:2 to 1:1.5.	Ratio of thickness to diameter 1:2.
Peripheral keel blunt.	Peripheral keel sharp.	Peripheral keel sharp.
4 or 5 whorls visible dorsally.	3 whorls visible dorsally.	3 whorls visible dorsally.
6 to 10 chambers in last whorl.	5 or 6 chambers in last whorl.	5 to 8 chambers in last whorl.
Sutures distinct, not excavated, transparent or opaque, form angle of 30° with margin.	Sutures distinct, somewhat excavated, transparent, form angle of 40° with margin.	Sutures distinct, not excavated, transparent, form angle of 35° with margin.
Ventral side with 6 to 10 primary, up to 9 suppl. chambers.	Ventral side with 5 or 6 primary, up to 5 suppl. chambers.	Ventral side with 5 to 8 primary up to 7 suppl. chambers.
Supplementary chambers as broad as visible parts of primary chambers.	Suppl. chambers much broader than visible part of primary chambers.	Suppl. chambers somewhat broader than visible part of primary chambers.
Test with hyaline umbilical filling.	Test without hyaline umbilical filling, sutures starlike.	Test without hyaline umbilical filling or starlike sutures.
Test less hyaline than in other generations, rather coarsely puntate.	Test hyaline, rather coarsely punctate.	Test hyaline, rather coarsely punctate.
Aperture a curved slit surrounded by fine papillae.	Aperture a curved slit surrounded by fine papillae.	Aperture a curved slit surrounded by fine papillae.
Diameter up to 0.45 mm.	Diameter up to 0.38 mm.	Diameter up to 0.30 mm.

Two zoospores after uniting form a rounded zygote which secretes the first chamber (proloculum) of the B-generation. This form in some species is the most hardy one as it is only found in the Zuiderzee in winter (Hofker 1930). In all species studied the form possesses the most primitive characters. Possibly this is the result of genetic factors or it may be simply a matter of size and space as is suggested by my study of the microspheric generations of *Spiroplectammina*, *Biloculina*, *Clavulina* and *Gaudryina*. In many species this longer living B-generation produces the largest tests which are often characterized by the accumulation of considerable secondary surficial calcareous material.

The microspheric generation propagates by the formation of plasmodiospores. These are masses of protoplasm, considerably larger than the zygotes that result from the

union of two zoospores. In many species they secrete the beginnings of a test before they become free and enter upon an independent existence. In some species the parental individual forms a kind of brood-chamber or an addition to its test which houses them

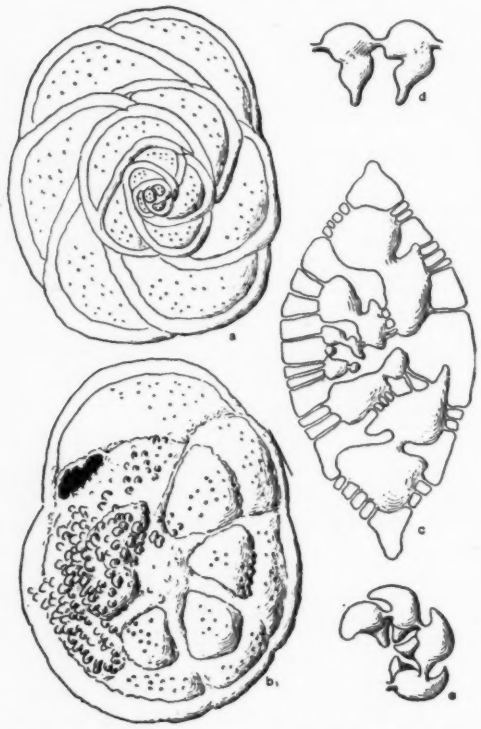

FIG. *3a*—dorsal view of megalospheric specimen of *Asterigerina gürichi* with small proloculum. *b*—ventral view of the same specimen, showing aperture with ventral and dorsal lobe, a large amount of pustules at the apertural side of the shell, and the broad central mass of chalk-substance. *c*—transverse section through the same specimen, filled up with paraffine. *d*—two adjacent chambers with their ventral lobes and their foramina, seen from the umbilical region. *e*—adjacent chambers, seen from above, with their ventral lobes (the supplementary chambers) below. All figures ×140.

(e.g., *Marginopora*, *Peneroplis*, *Polymorphina*). In some primitive species these plasmodiospores are formed by two individuals by means of a sexual union, as shown by Myers. In other species the microspheric individual forms a cyst by enclosing itself in mud. The test of the plasmodiospore (nucleoconch or protoconch) usually consists of two chambers whose walls are characterized by a somewhat thickened habitus, thicker than the walls of the later chambers. Some nucleoconchs, however, possess a greater number of chambers, e.g., *Orbitoides* and its allies.

The generation of individuals derived from plasmodiospores may produce zoospores. In this case there is a simple alternation of generations of A- and B-forms. Commonly, however, the A-generation propagates in the same way as the B-forms by means of plasmodiospores as I have determined occurs in *Rotalia* and *Miliola*. It is a remarkable fact, however, that plasmodiospores derived from a megalospheric individual produce nucleoconchs larger than that of their parent. This difference seems to result from some relationship between the total mass of an individual's protoplasm and the size of its nucleus or chromidium. Thus a species may be represented by a B-form or generation and several A-forms or generations. The former possesses a small proloculum, mostly of the size of 6–10μ, and each subsequent A-generation has a proloculum and nucleoconch larger than those of its predecessor. As the form and arrangement of subsequent chambers is influenced by the size of the proloculum, the mature tests of different generations may differ considerably from each other. For example in the genus *Rectobolivina*, the B-form shows a large number of biserial chambers, followed by some uniserial ones; the A_1-generation shows only a small number of biserial chambers and in the A_2-form the biserial part may be eliminated. Of course numerous intermediate generations may occur; but the fact remains, that statistically, considering the different shapes of generations in relation with the size of the proloculum, in many cases the three generations can be stated clearly, as I will show in a future paper.

With these facts in mind we must consider the composition of foraminiferal assemblages obtained from bottom samples such as those taken from the Zuiderzee. A sample obtained in spring will contain empty tests of the B-form, which had propagated a short time before, together with hundreds of young living individuals

of the A_1-generation. A sample collected in autumn, however, will contain empty shells of the A_1- and subsequent generations together with living specimens of the A_2-form. successive A-generations results in a constant, although generally slight, change in the living population. The B-form of *Rotalia flevensis* propagates in the Zuiderzee,

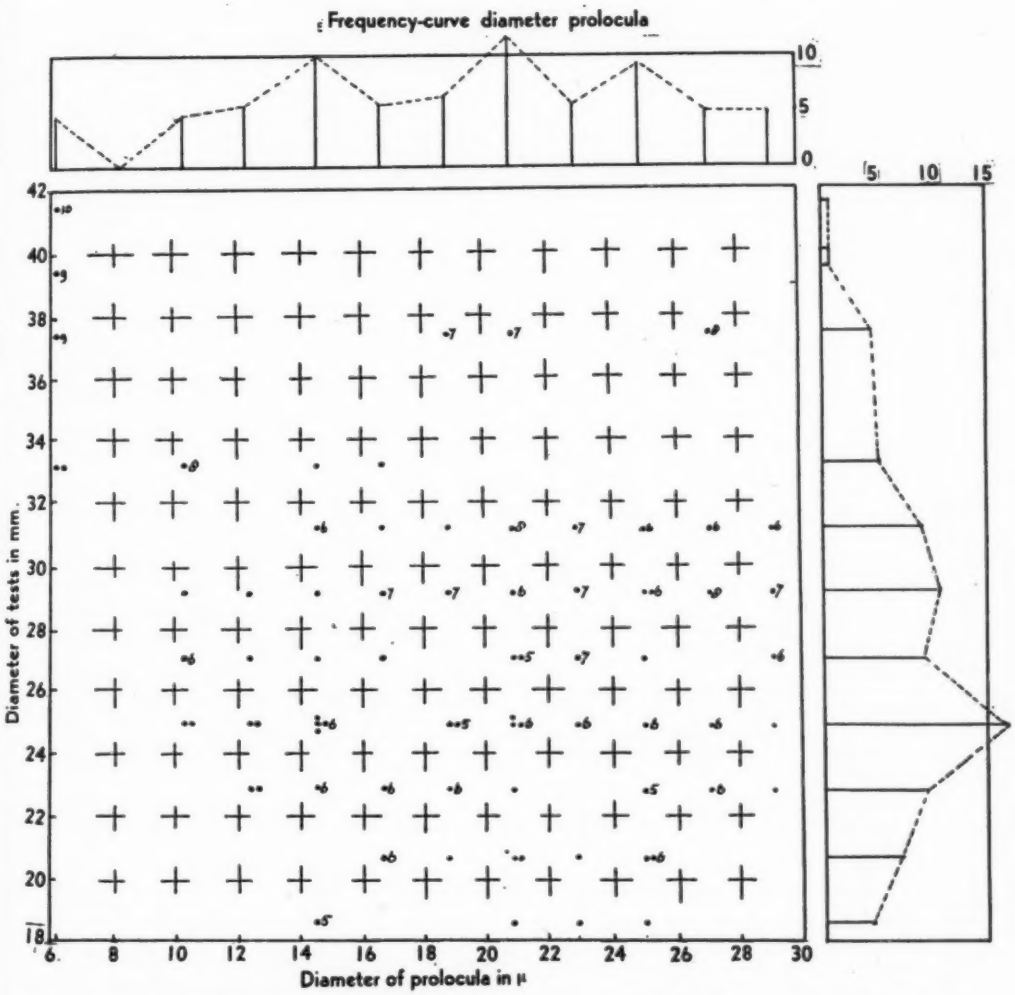

FIG. 4—Graph, showing relation between diameter of proloculum and largeness of total test of *Asterigerina gürichi*. This relation being rather poor, it suggests, that younger and older shells are found together. Numbers next points indicate number of chambers of last whorl.

Possibly some young individuals of the B-form may also be present.

The simple example shows that different forms of a single species may be obtained if samples are collected at different seasons of the year. In addition, however, the fact must be considered that propagation of the we may suggest, on about April 4th. The first A_1-generation becomes mature about May 1st and each individual gives rise to about 20 young with somewhat larger protoconchs. These may be full-grown about June 1st and this second A_1-generation produces about 200 third generation in-

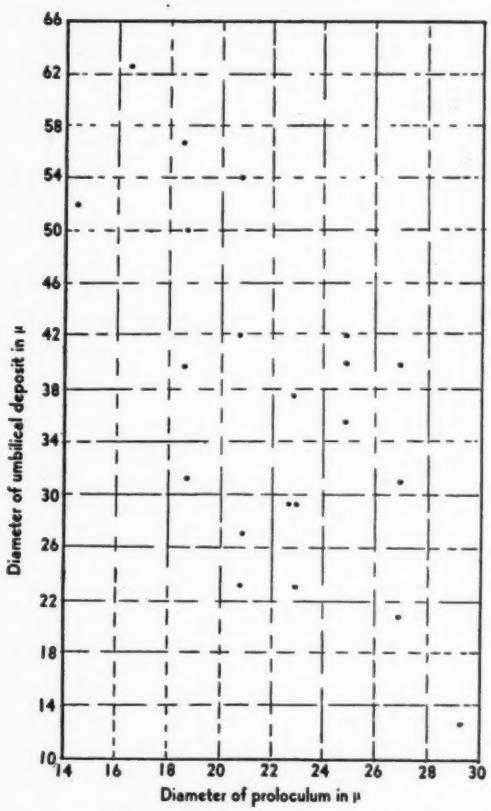

FIG. 5—Graph of relation between diameter of proloculum and width of umbilical deposit. When the diameter of proloculum increases, the width decreases in *Asterigerina gürichi*.

dividuals with still larger protoconch, which reach maturity about July 1st. This process continues until the first B-forms appear about September 1st, we may presume. A sample taken late in the summer may include some tests of B-form, some of the first A_1-generation, various intermediate forms and finally examples of the last A_2-generation. If a frequency distribution curve is prepared based upon measurements of the test length together with the proloculum diameter, several maxima may result such as have been found by investigators including Cosijn and myself. These indicate concentrations of individuals belonging to different subsequent generations. Some limited bottom samples, however, seem to include specimens of only a single generation which are all very nearly identical in their characters. This is what may often occur in geologic samples from drillings where only an exceedingly small area of bottom is represented.

If samples are studied from several localities obtained from beds of different age or depth the foraminiferal specimens are likely to possess recognizable differences because they are representatives of different generations as well as of different types, due to the different conditions, in which they were living. Unless these facts are completely understood within a species one is likely to conclude that he is dealing with different species, apply different names to

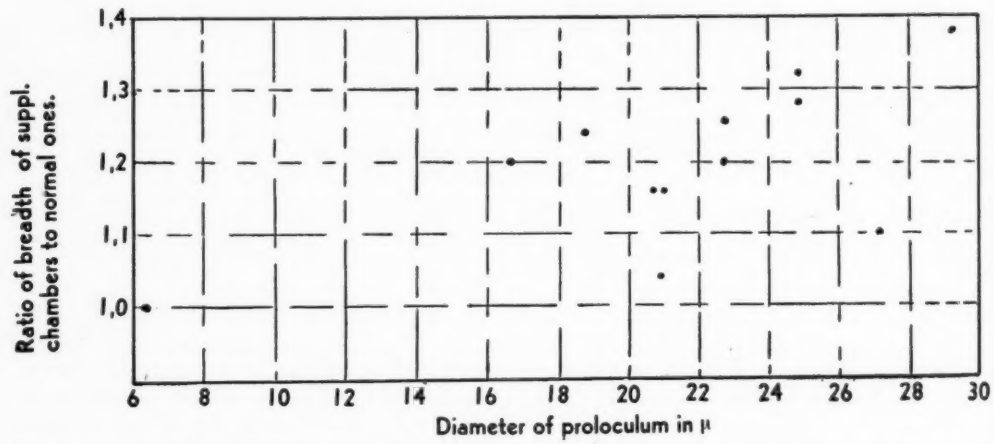

FIG. 6—Graph of relation of proloculum-diameter to ratio of width of supplementary chambers and that of normal chambers, of *Asterigerina gürichi*. The fraction has been multiplied with 2.

them, and draw faulty conclusions regarding the age and correlations of the strata involved. Foraminifera can be considered reliable guide fossils only when the bionomics of the various true species are completely known so that errors of this kind can be avoided. This is the type of mistake that was made by ten Dam and Reinhold when they described the supposed species *Asterigerina staeschei* and *A. frankei*.

The relations of environment to form, however, are equally important. This was brought to my notice very sharply by a study of *Bigenerina nodosaria* and *B. textularioides* from the Caribbean Sea. The former occurs in deep water, but the latter is invariably found in much shallower depth. A statistical analysis of the two species proves that their differences are related to environment and are not of specific significance. In both deep and shallow water all three generations have been recognized, so the relations of these two supposed species are not the same as those illustrated by *Asterigerina*, as previously discussed. Facies variation is quite different from specific differentiation as is well known to geneticists, because if environmental differences disappear, morphological differences disappear also. These forms may be known by different names but such names can have no true specific standing. Rhumbler has pointed out that in the example above the two forms should be termed *B. nodosaria* and *B. nodosaria* var. *textularioides* or *B. nodosaria-a*. To recognize them as different species would be comparable to splitting *Canis familiaris* into a hundred different species, which is obviously absurd.

The number of so-called species of Foraminifera is now said to be about 30,000, their synomyms are compiled to a number of about 150,000! If the relations of all these forms were adequately known this number of species could be reduced at the greatest to 3000. How many fossil "species" have been founded on a single specimen! Such reasonable reduction would not only greatly reduce confusion in matters of nomenclature and identification but would also provide much more reliable data for stratigraphic zonation and correlation. In many cases Foraminifera should not be relied upon as guide fossils until the various forms of each species are known and their bionomics have been subjected to careful statistical analysis. No species should be named without knowing the three generations of this species, so that it can be fully described.

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DOROTHY K. PALMER[1]

1897–1947

MRS. DOROTHY KEMPER PALMER died in Havana, Cuba, June 16, 1947. Her name may well be added to those of Chas. F. Hartt, C. B. Adams, and Wm. Gabb, outstanding pioneers in South and Central American geology, paleontology, and natural history, for each of whom an early death prevented the fulfillment of his training, knowledge, and enterprise.

Mrs. Palmer had already established a reputation as "one of the foremost authorities on Cuban fossil forams." She had accumulated basic worldwide foraminiferal material and in conjunction with her husband, Dr. Robert H. Palmer, had built up a large and valuable Cuban fossil collection.[2] Through the Palmers' geological and paleontological work in Cuba, as well as elsewhere in the Mexican-Caribbean and South American regions, and through Mrs. Palmer's employment as paleontologist with the Atlantic Refining Company from 1930–33, and from 1940 until her death, she had gained a wealth of firsthand information on the Foraminifera and the Cretaceous and Cenozoic stratigraphy of the mid-American area.

After her marriage, January 3, 1923, in San Antonio, Texas, accommodation to her husband's geological explorations meant frequent change. However, she delighted in the experiences in natural history which such travel brought, whether with bird, flower, star, or fossil. She was ever alert to learn, record, and assimilate new or pertinent data and enthusiastically persevered in trying to solve the faunal and stratigraphic problems of the Mesozoic and Cenozoic eras of the Caribbean province. To this end, her published studies of 10 titles on Cuban Foraminifera and one on the Foraminifera from Bowden, Jamaica, form a foundation upon which future work may be based. She considered her work as a part solution for a happy life. That she was not a closet-scientist will be vouched for by her fellow-workers with whom she was always willing to share material, information, or ideas. She was honored by her protégé and co-worker, Dr. Pedro J. Bermudez, in his dedication of the foraminiferal generic name *Palmerinella*, while she in turn showed respect to three major scientists in initiating the generic names, *Vaughanina*, *Cushmanella*, and *Torreina*.

Born in Chicago, Illinois, April 14, 1897, Mrs. Palmer received her secondary education in Los Angeles; entered the University of California in 1918 as one of the first three women majors in geology of that institution; was graduated in 1920 with honors in paleontology; in 1921–22, was assistant to the late Dr. Bruce L. Clark and worked with him on fossil Mollusca, receiving a M.A. in 1922. The results of their studies were published in 1923: her thesis on a dwarf fauna from the Eocene near Vacaville, California, and a joint paper on a revision of the important Eocene *Rimella*-like gastropods. Employment in 1924 by the Rio Bravo Oil Company in Houston marked the beginning of her studies of Foraminifera, for that was the initial period in America of development of techniques and investigation in the economic use of Foraminifera. In 1925–26, when her husband was obtaining his Ph.D. at Stanford University, Mrs. Palmer contributed articles to the first and third numbers of that enterprising mimeographed *Micropaleontology Bulletin* the experience in the writing of which helped train the pioneer group of micropaleontologists at Stanford.

In 1928 the Palmers were doing geological work in the State of Washington. Mrs. Palmer (1928–29) took graduate work, taught at the University of Washington,

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[2] Mrs. Palmer's foraminiferal library, notes, and material were left to the Paleontological Research Institution, Ithaca, N. Y., of which she was a member. The list of the Palmer Cuban fossil localities (3217 localities) has been published as no. 128, vol. 31, of *Bulletins of American Paleontology* by the Paleontological Research Institution. Robert Palmer died May 14, 1948.

and spent time at the Puget Sound Marine Laboratory. During that period she collected and began the investigation of the Astoria Miocene Foraminifera, a work which was to have been published with C. C. Church but which was never completed. In the summer of 1929, foraminiferal study was continued under the guidance of T. Wayland Vaughan at Scripps Institute of Oceanography, and she published her first paper on a foraminifer (JOUR. PALEONTOLOGY, vol. 3. In the fall she went to Cuba, where her husband was doing geological work, and where the main portion of the remainder of her life was spent. The Palmers were highly respected and loved by the Cubans. A mutual coöperation is evidenced by the fact that all, except the first, of Mrs. Palmer's Cuban papers, of either her own or joint authorship, were published in the Memorias de la Sociedad Cubana de Historia Natural.

Mrs. Palmer's death is deeply felt by her friends and colleagues, and the science of paleontology has sustained an inestimable loss.

KATHERINE VAN WINKLE PALMER

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HOLYNOCRINUS, NEW CRINOID GENUS FROM THE MIDDLE DEVONIAN OF BOHEMIA

JOSEF BOUŠKA
Praha, Czechoslovakia

ABSTRACT—Small, highly specialized, monocyclic crinoids from the Middle Devonian Hlubočepy limestone of Bohemia are referred to the new genus, *Holynocrinus*, which is especially characterized by having three plates in the radial circlet. Two new species (*H. moorei* and *H. spinifer*) are described. *Holynocrinus* is assigned to a new family, the Holynocrinidae, belonging in the order Disparata Moore and Laudon. The Holynocrinidae, however, seem to have no close relations with any previously known crinoids.

INTRODUCTION

VERY few crinoids have been described from Devonian rocks of Bohemia, particularly from upper strata of the system which have yielded abundant cephalopods, brachiopods, trilobites, and other invertebrates studied in the past century by J. Barrande (1850–1879) and more recently by other workers. The only known crinoid from these beds—*Ascocrinus bohemicus* Jaekel—was described (Jaekel, 1918, p. 57) from a single specimen showing incomplete diagnostic characters. Inasmuch as no other representative of *Ascocrinus* is known, it was omitted with good reason from the classification of Paleozoic crinoids by Moore and Laudon (1943). Accordingly, the discovery of any well-preserved crinoid from Devonian strata of Bohemia is worthy of note.

During the last twenty years several new middle Paleozoic fossil localities of considerable richness have been found and exploited by quarry operations in various parts of the "Barrandian" region, mostly in the vicinity of Praha. These range in age from the lowermost Budňany limestone ($e\beta_1$) of the Middle Silurian to the Hlubočepy limestone ($g\gamma$) of the Middle Devonian. Crinoid material from these new localities has been obtained by washing white soft clays found in pockets or holes that invariably occur along fissures of tectonic origin. The clays contain the same species as are observed in adjacent hard limestones. A large clay pocket discovered in 1931 at Holyně near Řeporyje occurs in the $g\gamma$ zone, which immediately underlies the h zone that yielded *Ascocrinus bohemicus* Jaekel. Many microcrinoids, mostly less than 2 mm. in maximum dimension, have been obtained by me from this clay. Most of these microcrinoids represent mature specimens belonging to about four new genera of the Synbathocrinidae, and some of them show early growth stages characterized by lack of development of the radial facets, as in Mississippian synbathocrinids from Texas described by Moore and Ewers (1942). In addition to these forms, other crinoids from Holyně are represented by immature specimens that show changes in the relative proportions of the radials which produce prominent bilateral symmetry of the cup. In 1932 I found in association with the synbathocrinids a cup having trimerous (trilateral) symmetry. Having only a single specimen, I supposed that this peculiar form was an abnormal individual belonging to one of the associated common microcrinoids or perhaps that it was an immature growth stage of some associated normal crinoid. Later, I made additional collections at Holyně and found four trimerous cups conspecific with the first. Also, I obtained growth series of another non-microscopic crinoid previously unknown to me that shows better defined pentamerous symmetry in young specimens than in adult specimens. These observations have made clear that the trimerous crinoids are neither immature examples of normal crinoids nor abnormal specimens, but that they comprise a distinct group of monocyclic inadunates for which I propose the name Holynocrinidae, new family.

SYSTEMATIC DESCRIPTIONS

Class CRINOIDEA Miller
Subclass INADUNATA Wachsmuth and Springer
Order DISPARATA Moore and Laudon
Family HOLYNOCRINIDAE, new family

Inadunate monocyclic crinoids having three plates in the basal circlet and three arm-bearing plates in the radial circlet.

Genus HOLYNOCRINUS Bouška, n. gen.

Monocyclic crinoids characterized by a small elongate cup that is trilobate in cross section comprise this genus. The dorsal cup has three basals and three radials. The basals are equal in size and shape; they are four-sided and the height of the basal circlet is about one-fourth the total height of the cup. The three plates forming the radial circlet are designated as left posterior radial (LPR), anterior radial (AR), and radianal (RA) (see generic diagram, fig. 8). These plates are almost equal in size and they differ only in form of the upper margins. The left upper portion of the RA protrudes slightly as a pouchlike bulge, and its left upper margin has a low, lunate depression for reception of an anal. The radial facets are narrow, occupying about one half the width of the plates. The arms are unknown, but judging by dimensions of the radial facets, they are thin. The column is unknown.

Genotype, *Holynocrinus moorei*, n. sp. Middle Devonian, Bohemia.

Discussion.—The new genus *Holynocrinus* is a highly specialized crinoid, as shown by the peculiar structure of the cup, especially in having only three plates in the radial circlet. The cup is plainly monocyclic and it must be added to the order Disparata Moore and Laudon. Not only among crinoids of this order, which comprises primitive monocyclic forms, but among others there is no known crinoid that has such symmetrical trilateral structure as *Holynocrinus*. A tendency toward dominance of three rays is well known in some other crinoids, such as the Permian Sundacrinidae, but these retain five plates in the radial circlet. In the cup of the sundacrinids, which is dicyclic, three radials are arm-bearing and the other two (LAR, RAR) are smaller and not arm-bearing. In some genera of the monocyclic families Allagecrinidae and Pisocrinidae, two or three radials are much larger than the others, but arms usually are present in all five rays. A few examples of echinoderms having three rays occur in non-crinoid Pelmatozoa, such as *Arachnocystites infaustus* Barrande and *Hemicosmites extraneus* Eichwald. In the latter, as figured by E. Haeckel (1896, pl. 4, fig. 15), the oral side of the theca bears three facets in the manner of *Holynocrinus*. Most blastoids are pentamerous, but some specimens show the absence of one or two radials. Such specimens are representatives of *Schizoblastus* from the Permian strata of Timor described by Wanner (1924) and examples of *Pentremites* reported by Hambach (1903). These specimens are abnormal and no systematic value should be attached to them.

Both *Holynocrinus moorei*, n. sp., and *H. spinifer*, n. sp., belong to the microcrinoids and like the pisocrinids and other small crinoids from Silurian and Devonian strata they are considerably older than the tiny crinoids described from Carboniferous and Permian rocks.

It is worthy of note that the Middle Devonian, especially the coral-bearing horizon in the Eifelian stage of Germany, has yielded a number of highly specialized forms that have long been known. These include *Tiaracrinus* Schultze, *Nanocrinus* Müller, *Cupressocrinites* Goldfuss, and *Gasterocoma* Goldfuss, which are specialized in having four rays in the cup or column; but there is no close relationship between these genera and *Holynocrinus*. *Nanocrinus*, *Cupressocrinites*, and *Gasterocoma* are dicyclic crinoids. *Tiaracrinus* is monocyclic but differs considerably from *Holynocrinus* in the structure of the upper portion of the cup and tegmen, the arms being rigidly joined to the orals.

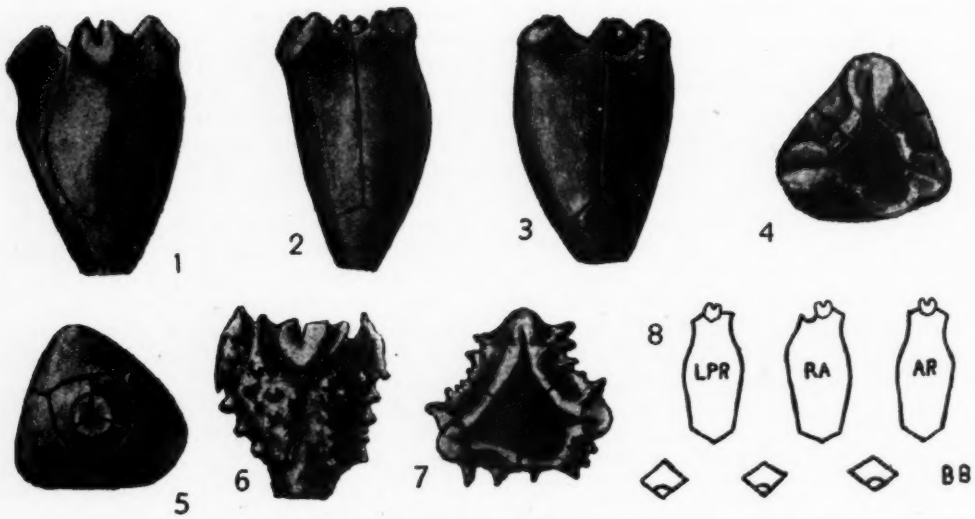
As regards structure of the anal area of *Holynocrinus*, comparison is suggested with *Hybochilocrinus* Weller among the Allagecrinidae. In this pentamerous microcrinoid a cut occurs on the left shoulder of the RPR in the same position as on the RA of *Holynocrinus*. The narrow radial facets of *Holynocrinus*, in combination with trimerous symmetry, suggest the Ordovician *Hybocystites eldonensis* Parks of the family Hybocrinidae. In the latter the tendency to three-

rayed structure is well marked, but the presence of five plates in the radial circlet, the globular shape of the cup, the presence of anal X in the cup, and inequality of the plates are characters very unlike those of *Holynocrinus*.

HOLYNOCRINUS MOOREI Bouška, n. sp.
Figures 1–5

Description of this species is based on five well-preserved cups, which range from 1 to 1.8 mm. in height. All of these fully correspond with the characters of the holotype, which is 1.7 mm. high and 1.2 mm. in maximum width.

The cup is elongate, contracting somewhat upward. It is trilobate in cross section in the middle portion of the cup. At the top it has the shape of a triangle with the radial facets at its corners. The outline of the cup is dissimilar in different lateral views. Viewed from the right anterior interray, the left side of the cup is straight and the right side is convex in the upper part. In posterior view, the left side is more convex than the right, and in anterior view, the sides of the cup seem to be symmetrical. Between radial facets there are small gaps, which are V-shaped on both sides of the AR, while in the posterior interradius the gap is semicircular and pushed aside to the radial facet of the RA; probably this notch served for the reception of an anal. The radials are elongate, the height being twice the width; their upper margins slope inward so that, viewed from the summit, they form an angle of 60 degrees. The radial facets are elliptical in outline and they bear well-marked very narrow ambulacral grooves. The left upper part of the RA bulges outward to form a pouch, which is best seen in ventral view. The stem facet is circular, having a diameter of 0.3 mm. in the holotype. The surface is smooth and sutures between the plates are plainly visible in all the specimens.



EXPLANATION OF FIGURES

FIGS. *1–5*—*Holynocrinus moorei* Bouška, n. gen. n. sp. *1*, anterior, view; *2*, view on interray between radianal and anterior radial; *3*, posterior view; *4*, ventral view; *5*, basal view. All figures ×20. (p. 522)

6, 7—*Holynocrinus spinifer* Bouška, n. sp. Anterior and ventral views of the holotype, both ×20. (p. 523)

8—Generic diagram of *Holynocrinus*, Bouška n. gen. (p. 521)

Remarks.—*Holynocrinus moorei*, n. sp., differs from *H. spinifer*, n. sp., in proportions of the cup, that of *H. spinifer* being lower and broader, and in the smooth surface of the plates. *H. moorei* is associated with the cephalopod *Anarcestes plebeius* (Barrande), which is the index fossil of the

gγ zone of the Middle Devonian of Bohemia.

The specific name is given in honor of Prof. R. C. Moore.

Horizon and locality.—Middle Devonian, Hlubočepy limestone (*gγ*), central Bohemia, Holyně at Řeporyje.

Holotype.—J. Bouška Coll., No. E301.

HOLYNOCRINUS SPINIFER Bouška, n. sp.
Figures 6, 7

This species is based on a single specimen. The height of the cup is 1.25 mm. and the maximum width is 1.2 mm. The sutures between the plates are hidden by strongly developed surface ornamentation, which consists of short, thick, irregularly disposed and unequally sized spines. The edges of the radial facets are bordered by thin, sharp ridges which taper laterally to the top of the cup.

Remarks.—*Holynocrinus spinifer*, n. sp., differs from *H. moorei*, n. sp., in proportions of the cup, as already noted, and in having spinose ornamentation. The shape of the RA and the triangular summit of the cup are alike in both species and are the important features of the genus *Holynocrinus*.

Horizon and locality.—Middle Devonian, Hlubočepy limestone (*gγ*), central Bohemia, Holyně at Řeporyje.

Holotype.—J. Bouška Coll., No. E306.

NOTE.—I am obliged to Professor Raymond C. Moore of the University of Kansas, who has read the manuscript and given me helpful advice. I express thanks also to American paleontologists who have sent me valuable publications, enabling me to continue studies of Bohemian Paleozoic fossils.

The drawings in this paper have been made from the type specimens using a special pantograph of my own construction.

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JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 4, PP. 525–532, 4 TEXT FIGS., JULY 1948

PALEONTOLOGICAL NOTES

UPPER CRETACEOUS FORAMINIFERA OF MINUTE SIZE IN THE MARINE PLEISTOCENE (ICENIAN) SANDS OF THE NETHERLANDS

J. H. VAN VOORTHUYSEN
Netherlands Geological Survey, Haarlem

A test boring by the Zuiderzee Reclamation Service to explore the deeper Quaternary strata (1946, pp. 19–20) was made near Harderwijk in the center of a zone which is downwarped about 200 meters. In the lower part of the Icenian sands at a depth of 332 to 335 meters, minute Upper Cretaceous Foraminifera were found in association with the following rather poor indigenous fauna:

	Size	
Elphidiella arctica (P. and J.)	0.4 mm.	common
Rotalia beccarii (L.)	1.0 mm.	"
Elphidium incertum var. clavatum (Cush.)	0.4 mm.	locally common
Quinqueloculina seminulum (L.)	1.5 mm.	common only in lower part

This fauna suggests a lagoonal-littoral habitat of an arctic-boreal climate. The absence of *Q. seminulum* from the upper strata indicates that a change to brackish water facies may have occurred.

The Cretaceous specimens which attain an average size of about 0.15 mm. are as follows:

Gümbelina striata (Ehr.).	common
Globigerinella aspera (Ehr.).	"
Globigerina cretacea (d'Orb.).	rare
Discorbis sp.	very rare
Cibicides sp.	"
Bolivina sp.	"
Globorotalites cf. *micheliniana* (d'Orb.).	"
Buliminella cf. *ovula* (Reuss).	"
Buliminella cf. *obtusa* (d'Orb.).	"
Other undetermined species	"

The Cretaceous specimens are recognizable because they are filled with white opaque material and are more or less eroded. Their rather uniform size suggests selection by a transporting medium. Glaessner (1945, 207, 208) has pointed out that reworked Upper Cretaceous Foraminifera are rather common in some younger sediments (see also Gubler, 1943).

Redeposited Foraminifera have not been recorded previously in the post-Cretaceous sediments of the Netherlands, but because

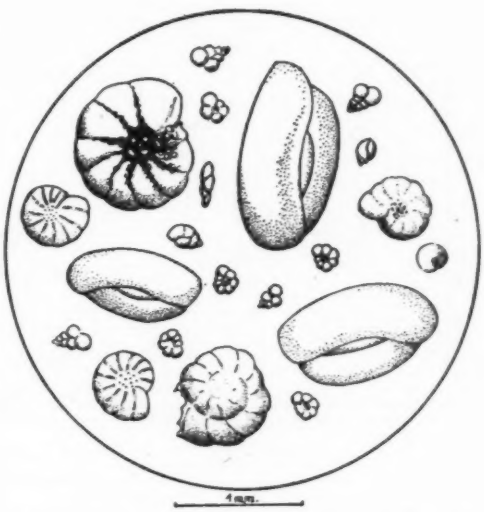

FIG. 1—Redeposited Upper Cretaceous Foraminifera and indigenous forms found associated in the lower part of the Icenian sands.

of their minute size they may have been overlooked at many places. The occurrence of this fauna at Harderwijk, which belongs to the Globigümbelite facies of the Upper Cretaceous (Brotzen, 1936, pp. 16, 17), probably indicates the erosion of nearby land resulting from the lowering of sea-level.

The southeast coast of England or the Munster basin of Germany may have been the source of these specimens. As Macfadyen has suggested (1938, p. 411), Upper

Cretaceous Foraminifera may have been contributed to the Pliocene-Pleistocene sediments by erosion either of the Chalk outcrops or of glacial till. The till of the Netherlands is now being examined for Foraminifera, but as the Icenian sands were deposited before the expansion of the Riss icesheet the fauna under consideration could not have been obtained from this source. Also the abundance of specimens and their restriction to a narrow zone make it seem unlikely that they have been redeposited several times. Probably, therefore, they were obtained directly from Cretaceous outcrops as a result of the lowering of sea-level and the rejuvenation of erosion. This interpretation is supported by the fact that indigenous faunas of the Icenian sands and silts indicate shallowing of the sea and transition from littoral to brackish water lagoon conditions.

Nearly 100 years ago von der Marck studied the redeposition of older fossils in Quaternary sediments in Germany, and listed both macro- and microfossils, including Foraminifera and recorded their abundance (1858, pp. 25, 26, 53–57).d

A map showing the extension of the North Sea during early Pleistocene time reveals that the nearest possible source of the Harderwijk specimens is the Munster basin.

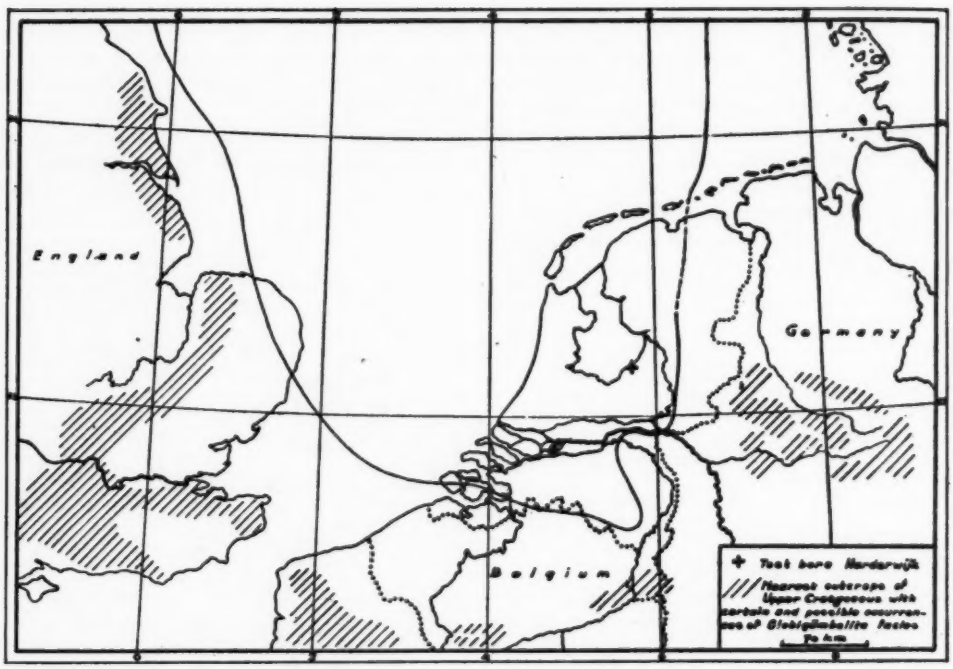

FIG. 2—Map showing extent of the North Sea during early Pleistocene time (after Tesch, 1942).

Next, is the South-Limburg district of the Netherlands and Belgium and still farther are the outcrops of southeastern England and their continuation in France.

At present it is impossible to determine whether the Harderwijk specimens were transported by streams from the Munster basin or South-Limburg or by sea currents from the British Isles. In either case they were moved farther than similar specimens that have been noted in England and Germany. Further investigation of this problem may throw important light on the Pleistocene paleogeography of northeastern Europe. Detailed study of Upper Senonian

(Maastricht chalk and Kunrade limestone) Foraminifera of South-Limburg, now in progress, may furnish additional pertinent information.

In the study of sediments, reworked faunas of this type should not be overlooked. The evidence which they furnished may be even more important than that derived from the heavy minerals.

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CONODONT HOMONYMS AND NAMES TO REPLACE THEM

E. B. BRANSON AND M. G. MEHL

In 1943 Branson and Mehl recognized the homonyms listed here, excepting *Trichognathus*, and proposed new names in their chapter on conodonts in Shimer and Shrock's North American Index Fossils. They planned to submit an explanatory note to Science at the same time but failed to do so.

Centrognathus Branson and Mehl, 1933, Univ. Missouri Studies, vol. 8, p. 196, is a homonym of *Centrognathus*, F. E. Guerin-Memeville, Rev. Zool. vol. 3, p. 79, 1840, Col. Scarab. Ceton. *Centrognathodus* was substituted by Branson and Mehl in Index Fossils of North America, 1943, p. 240. The date 1942 was given as they expected their note to appear in that year.

Centrognathodus Branson and Mehl, 1943. Denticulate bar with anterior end bent inward and a denticulate spur extending outward from near the bend; denticles subcircular and normally discrete.

Trichognathus Branson and Mehl, 1933, Univ. Missouri Studies, vol. 8, p. 36, is a homonym of *Trichognathus* A. Berthod, Latreille's Fam. Thierr, p. 327, 1827, Col. Carab.

Trichonodella, new name, is proposed as a substitute. Dental unit bilaterally symmetrical with deeply excavated base. A backward curved main denticle with three denticulate bars, two extending laterally and one posteriorly.

The main difference between *Hibbardella* and *Trichonodella* is the presence of the basal excavation in the latter.

Solenognathus Branson and Mehl, 1933, Univ. Missouri Studies, vol. 8, p. 270, is a homonym of *Solenognathus*, W. Swainson, 1839. L. Agassiz Nomencl. Zool.—Index pp. 343 and 344, 1846, Pisc. Teleost. *Solenodella* Branson and Mehl, was proposed as a substitute in Index Fossils of North America, 1943, p. 244.

Solenodella Branson and Mehl, 1943. Blade-like, moderately arched dental units with confluent denticles; a lateral flange or shelf on one side for the full length of the base; an elongated slightly expanded navel at or somewhat back of midlength; the oral edge of the blade irregularly crenulate; each point formed by the free end of a denticle.

Pinacodus Branson and Mehl, 1933, Univ. Missouri Studies, vol. 8, p. 269, is a homonym of *Pinacodus*, (L. Agassiz M.S.) J. W. Davis, Tr. R. Dublin Soc. ser. 2, vol. 1, p. 476, 1883, Pisc. Elasm. *Pinocognathus* was substituted by Branson and Mehl in Index Fossils of North America, 1943, p. 244.

Pinocognathus Branson and Mehl, 1943. Dental units short, deep; comparatively thick blade with sharply crenulate rather than denticulate oral edge, small pit at midlength of aboral edge.

Siphonognathus Branson and Mehl, 1933, is a homonym of *Siphonognathus*, J. Richardson, P. Zool. Soc. London, vol. 25, p. 237, 1858, Pisc. Teleost. *Siphonodella* was substituted by Branson and Mehl in Index Fossils of North America, 1943, p. 245.

Siphonodella Branson and Mehl, 1943. Dental units similar to *Polygnathus*, but differs in having a spout-like projection at the front end.

The authors expected that this note would be published in the November 1947 number of the JOURNAL OF PALEONTOLOGY but the manuscript was returned in September for emendations. Branson was in the field at this time and the manuscript was not found until February 1, 1948. The name *Trichonodella* was used by E. B. Branson and C. C. Branson (Lower Silurian Conodonts from Kentucky, JOURNAL PALEONTOLOGY, vol. 21, pp. 551–552) under the supposition that this note would appear in the same number of the JOURNAL.

A NEW SPECIES OF HYDROZOAN FROM THE ATHENS SHALE OF VIRGINIA

CHARLES E. DECKER
University of Oklahoma, Norman, Oklahoma

Two specimens of a new species of hydrozoan were found in the Athens shale, 2 miles east of Staunton, Virginia, associated with a large number of well-preserved graptolites sent to me from Harvard University by P. E. Cloud, Jr. The collections were secured from this locality in 1921 by the Shaler Memorial Expedition.

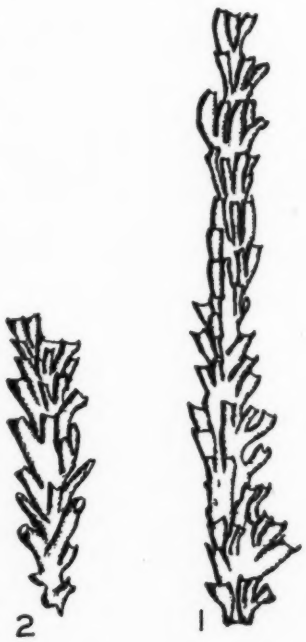
These specimens differ from the graptolites in the irregularity of their hydrothecae and in their preservation as a white film on the rocks.

DESCRIPTION OF SPECIES

Genus ARCHAEOCRYPTOLARIA
Chapman 1919
ARCHAEOCRYPTOLARIA COMPACTA
Decker n. sp.
Figures 1, 2

The species name, "*compacta*," is proposed because the hydrothecae lie compactly together around the stipe. Some of them extend parallel with the elongated axis, while others are inclined at a small angle. The distal ends of only a few hydrothecae project laterally a short distance beyond the margin of the stipe. The hydrothecae are arranged irregularly around the stipe, and they vary in size. They are nearly cylindrical and have circular apertural openings. They occur 8 to 10 in 10 mm. The holotype shown in figure 1 has a length of 20 mm. and a width of 2 to 2.5 mm.

Discussion.—While this species differs considerably from recent hydroids dredged by the Challenger expedition, it seems most



FIGS. *1, 2*—*Archaeocryptolaria compacta* from the Athens shale, 2 miles east of Staunton, Virginia (×4). *1*, the holotype, Museum of Comparative Zoology, Harvard; *2*, a paratype, University of Oklahoma.

like the form described as *Grammaria insignis* (Allman, 1888). This new species has more hydrothecae than recent hydrozoans, and they are more irregularly arranged. The fossilized stipes are white like those from the Middle Cambrian of Victoria, Australia (F. Chapman and D. E. Thomas, 1936) but they do not seem to have been changed to Gümbellite, the silvery substance to which graptolites are sometimes altered by metamorphism. Associated graptolites in the Athens shale are composed of the usual dark substance.

The following graptolites, which are characteristic or more common in the lower part of the Athens shale at this locality have been identified:

Cryptograptus tricornis (Carruthers)
Diplograptus (*foliaceous*) *acutus* Lapworth
Glossograptus ciliatus Emmons
Orthograptus (*calcaratus*) *incisus* Lapworth
Nemagraptus gracilis (Hall)

Many other species have also been identified from the lower part of the formation.

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OCCURRENCE OF *LEPIDOCYCLINA PUSTULOSA* (H. DOUVILLÉ) IN MOROCCO

T. F. GRIMSDALE
New Malden, Surrey, England

Long familiarity with upper Eocene Lepidocyclinids from the Caribbean region, in particular with the group of variants centering round *Lepidocyclina pustulosa* (H. Douvillé), has convinced the writer that the form described as *Lepidocyclina mauretanica* (Bourcart & David) from the Eocene of Morocco, is practically identical with *L. pustulosa* as redefined by Vaughan & Cole (1941, p. 65).

A suite of excellent figures of *L. pustulosa* is to be found in the aforementioned publication by Vaughan & Cole, while Brönnimann (1940) has provided a number of fine illustrations of the Moroccan species. Comparison of these figures should at once satisfy anyone at all familiar with the *Lepidocyclinidae* that *L. mauretanica* falls well within the range of variation of *L. pustulosa*, the synonymy of which may now read as follows:—

LEPIDOCYCLINA PUSTULOSA (H. Douvillé)

1917. *Isolepidina pustulosa* H. Douvillé, p. 844, text figs. 1, 2, 3, 4.

1933. *Isolepidina mauretanica* Bourcart and David, p. 48, pl. 3, fig. 2; pl. 4, fig. 1; pl. 6; fig. 2; pl. 12, figs. 4, 5; text fig. 3.

1940. *Lepidocyclina* (*Isolepidina*) *mauretanica* (Bourcart and David), Brönnimann, p. 37, pl. 3, figs. 7, 8, 10, 11, 13, 14; pl. 4, figs. 1–3; pl. 5, figs. 5, 8; text figs. 7, 8.

Lepidocyclina (*Isolepidina*) *mauretanica*, var. *minor* Brönnimann, p. 40, pl. 3, fig. 12; pl. 5, fig. 6.

1941. *Lepidocyclina* (*Pliolepidina*) *pustulosa* (H. Douvillé), Vaughan and Cole, p. 65, pls. 25–30.

These authors give a very full synonymy of the American occurrences of the species, which is accepted here.

The significance of this identity is considerable, since it re-opens the whole question of the connection between the Lepidocyclinids of the New World with those of the Old World. Moreover, it suggests that the abundant Asterocyclinids which accompany both the American and African examples of *L. pustulosa*, but are referred to distinct species, may also prove to be identical.

It is to be hoped that other workers may be led to institute detailed comparisons among

various groups of fossils in, e.g., Trinidad and Morocco. Such a task might prove more fruitful than has previously been suspected.

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SECTIONING SMALL FORAMINIFERA

ALAN WOOD
University College of Wales, Aberystwyth

While making an investigation of wall structure I have recently had to section very many small Foraminifera. The following method, developed from one used at Imperial College, London, for many years, gives good results.

Immerse the foraminifer in xylol to which a little canada balsam has been added. Allow to evaporate naturally, a process usually taking several days. This ensures the penetration of canada balsam into the interior. Mount a piece of mica, about ¼ of an inch square, on a microscope slide. Place the specimen on top of the mica in balsam, and gently heat till the balsam, when tested, is hard. Grind down the foraminifer to the desired plane with finest laevigated carborundum powder. Wash, flake off the mica with the foraminifer adhering to its upper surface. Mount again upside down. When the balsam is hard flake off the mica and grind down the other side of the specimen until the desired thickness is attained.

The use of the mica ensures that the two sides of the section are absolutely parallel.

MAGNETIC SEPARATION OF MICROFOSSILS

RUTH A. M. SCHMIDT
U. S. Geological Survey, Washington, D. C.

During the study of the ostracode fauna of certain glauconitic beds of the Atlantic Coastal Plain, magnetic separation of the microfauna was found to be quite successful as a preparation technique. The method may be of interest to other micropaleontologists.

The use of heavy liquids and decanting methods proved unsatisfactory, as many shells were filled with glauconite or clay and could not be floated off.

Washed material was screened, and that retained on size 50 to 110 mesh screens was saved for further separation and study. A large electromagnet was used first for a coarse separation of most of the glauconite. The fossiliferous remainder was further refined with a Frantz isodynamic separator which was most successful in treating the smaller sizes. Within thirty minutes a sorted sample was separated and ready for picking. A current of 1.2 amperes, a tilt of 2½ degrees toward the magnetic side, and a tilt toward collecting tins depending on size of grains, produced the best results. This method is an excellent time-saver in han-

dling highly glauconitic samples, and separation is good.

The Frantz isodynamic separator is a special type of equipment used in research laboratories as an adjunct to heavy-mineral separation. It consists of a powerful, adjustable electromagnet, a vibrating chute of nonmagnetic metal, feeders and collecting tins. Both the cross slope and the longitudinal slope of the chute can be adjusted. It is fully described and illustrated in AIME Technical Publication 1549.[1]

[1] Gaudin, A. M., and Spedden, H. R., 1943. Magnetic separation of sulphide minerals. Mining Technology, A.I.M.E. Tech. Pub. 1549, pp. 1–13.

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AN ORDOVICIAN TRILOBITE AND SOME LATER PALEOZOIC CRUSTACEA IN MOULTING POSITIONS

MARTIN F. GLAESSNER
Port Moresby, Papua, New Guinea

From the nature of growth and fossilisation in typical Crustacea and trilobites it is obvious that many fossils belonging to these groups represent not the remains of dead animals but shells cast off in the periodic process of moulting. It is, however, an uncommon occurrence to find remains of these arthropods preserved with the parts of their skeletons still in the positions in which they were placed by the movements of the moulting animals. A recently published figure of a specimen of the trilobite *Telephus* from the lower Athens formation (Chazyan) of Virginia gives an excellent example of what must have been the moulting position of an Ordovician trilobite. In this specimen "The pygidium and thorax remain in articulation and are somewhat compressed toward the left. The free cheeks have been slightly shifted, and the eyes crushed. The glabella has been overturned and carried forward, so that it now rests upside down and is longitudinally reversed" (Fischer 1946, p. 566). The preservation of trilobite remains with the thorax and pygidium in articulation and the head detached and turned upside down and back to front was first discussed by Salter in 1862 and more recently studied in considerable detail by R. Richter (1937). A comprehensive review of factors which might have been involved in this displacement of part of the trilobite skeleton led the author to the conclusion that it could have been caused only by moulting, that is, the escape of the animal from an opening between the cranidial and thoracic parts of its integument. He listed eight species of *Phacops* from the Upper Devonian and one from the Middle Devonian, one species of *Phacopidella* (Middle Devonian) and one *Asteropyge?* (Lower Devonian) as the only trilobites in which he observed a similar preservation of cast shells. The fact that this moulting position is common only in Phacopidae with reduced eyes (Upper Devonian) was explained by Richter as the result of easier and more rapid moulting in this group and consequently less frequent scattering of parts of the cast integument. The specimen of *Telephus* indicates that the same type of moulting occurred also in other families in which facial sutures and eyes remained functional but it is evident that under these conditions preservation of an entire specimen in moulting position is exceptional. Referring to the present writer's earlier studies of moulting positions in fossil Decapod Crustacea and their significance (Glaessner 1929), Richter pointed out that fossilisation of a cast shell with its disjointed parts in their original arrangement indicates that the animal actually lived in the locality in which its remains are found. This type of fossil reflects a phase in the normal biological

activity of the species. It also indicates complete lack of movement of water or sediment at the time of deposition.

Excellent examples of moulting positions in higher Paleozoic Crustacea are found among the specimens illustrated in a monograph by Peach (1908) on this group of fossils from the Carboniferous of Scotland. Peach misunderstood the significance of the frequently observed displacement of the carapace, particularly in the Perimecturidae. He figured a recent *Mysis* in typical moulting position but described it as an "Attitude assumed on dying" (l.c., p. 39, pl. 6, fig. 8). It is exactly the attitude in which the discarded integuments of many macrurous Decapod Crustacea are found when left undisturbed after moulting.

A small crustacean from the Mississippian of Montana described (H. W. Scott 1938) as representing a new genus *Squillites* resembles *Perimecturus*. According to Scott "all eight thoracic somites are exposed posterior to the carapace." This may be due to displacement of the carapace similar to that observed in most of Peach's specimens.

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JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 4, P. 533, JULY 1948

REVIEW

ÜBER MORPHOGENETISCHE UNTERSUCHUNGEN AN GROSSFORAMINIFEREN, by Otto Renz and H. Küpper—Eclogae Geologicae Helvetiae, vol. 39, No. 2, 1946 (published in 1947), pp. 317–342, 8 text figures, 8 tables, and 1 chart. E. Birkhäuser, Basel, Switzerland.

Since the importance of the stratigraphic application of the larger Foraminifera for economic purposes was recognized, study in this field of geologic science flourished increasingly. A continuous flood of more or less accurate descriptions of organisms supposed to be newly discovered species, subspecies, and varieties published in many languages set in. Age assignments were often doubtful and ecologic conditions were seldom mentioned. Because the amount of data was rapidly increasing, it became impossible for a single worker to evaluate it critically in its entire scope. As a result, more and more paleontologists specialized in a single family or in a few families of the larger Foraminifera. It is from this group of specialists that a more critical attitude concerning the validity of the criteria used as a basis for the taxonomy of the larger Foraminifera originated. This attitude evolved to a distinct trend of research, the morphogenetics of the larger Foraminifera. Its methods parallel principally those applied in macropaleontological morphogenetics. They are impeded, however, by the fact that they are based on microscopic studies of minute and complicated internal structures which are usually not readily accessible. In spite of this and in consideration of the paucity of available data, the results already obtained by the small group who specialize in this new field of study may be called remarkable. Their work not only interests paleobiologists, but promises to yield a large amount of stratigraphic information that will be applicable for economic purposes

Unfortunately, publications dealing with these studies are scattered through various periodicals and written in four languages. In recent years, therefore, a want was felt for a competent and concise compilation of the latest results in this field. The paper under review fills this need, useful aspects of this branch of science are considered and, finally, lines along which future studies should proceed are mentioned. The paper is replete with text figures and tables in the text. A commendable feature is the excellently composed chart arranging major morphogenetic, stratigraphic, and paleogeographical data into a clear and convenient scheme. The chart is very pleasing in its appearance, and it is a valuable compilation of information. References given at the end of the paper include the more important contributions on which the authors largely rely.

The paper opens with a chapter introducing the non-specialist to the methods of morphogenetic research and their application to oil geology. It then proceeds with a systematic treatment of the genera involved that reflects a careful study of the literature. The paper closes with a chapter including a brief summary of present knowledge and recommendations concerning the stratigraphic application of morphogenetics. Some readers may wish that in the discussion on the application of morphogenetics to stratigraphy and oil geology the relations between morphogenetics and ecology might have been mentioned, though not much is actually known about these problems.

Some errors have escaped the proofreader. American, English, and Dutch readers will ponder over the misspelling of English titles mentioned in the section on literature and the names of two Dutch paleontologists. These errors, however, do not impair the paper seriously.

Viewed as a whole, the paper has assembled into suitable form and has discussed competently the pertinent data of this branch of science. It represents well the present state of our knowledge in this field. The authors are to be commended on this clear and welcome study.

J. G. BURSCH

JOURNAL OF PALEONTOLOGY, VOL. 22, NO. 4, PP. 534–540, JULY 1948

SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE TWENTY-SECOND ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The twenty-second annual meeting of the Society of Economic Paleontologists and Mineralogists was held in Denver, Colorado, April 27–29, 1948, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

The Presidential Address of the Society, "Stratigraphy and Paleogeography of the Catahoula-Frio Formation," was given by James A. Waters in the joint sesssion on Tuesday, April, 27, 1948.

The first part of the technical program of the Society, with W. C. Krumbein and W. H. Twenhofel presiding, began at 9:30 A.M., Wednesday, April 28, and continued until 4:00 P.M. The following papers were presented in the order given.

E. L. Lucas, "Petrographic Character of some subsurface beds in Cleveland County, Oklahoma"

S. A. Wengerd, "Lithologic variations of the Viola limestone of the Arbuckle geosyncline"

Raymond Sidwell, "Sediments at southern termination of the Sangre de Cristo anticlinorium, New Mexico"

G. L. Robb, "Origin of Red Bed coloration"

M. K. Elias, "Paleontology of the Upper Mississippian in Meade County, Kansas"

Symposium on Environmental Significance of Dwarf Faunas

Cecil G. Lalicker, "Protozoa"

Preston E. Cloud, Jr. (read by E. C. Dapples), "Brachiopoda"

Bernhard Kummel, "Ammonoidea"

H. B. Stenzel," Mollusca (exclusive of Ammonoidea)"

Harold W. Scott, "Crustacea"

The second part of the technical program with H. B. Stenzel presiding, began at 9:00 A.M., Thursday, April 29, and continued until 11:00 A.M. The following papers were presented.

Charles E. Decker, "Five new graptolites from Tennessee and Virginia"

J. Harlan Johnson and B. J. Ferris, "Tertiary coralline algae from the Dutch East Indies"

J. Harlan Johnson, "The importance of coralline algae in reef building at Bikini, Marshall Islands"

L. W. LeRoy, "The Foraminifer *Orbulina universa* d'Orbigny as a possible Middle Tertiary time indicator"

Edward J. Zeller, "The stratigraphic significance of Endothyroid foraminifera"

The third part of the technical session, with W. C. Toepelman presiding, began at 1:30 P.M., Thursday, April 29, and continued until 4:00 P.M. The following papers were presented in the order given.

George Gryc, "Macrofossil and microfossil studies, Northern Alaska"

Ernest H. Lathram, "Heavy mineral and thin section studies, Northern Alaska"

W. C. Krumbein, "Principles of regional sedimentary stratigraphic analysis"

E. C. Dapples, W. C. Krumbein and L. L. Sloss, "Associations of lithologic and tectonic environments in the Central States"

August Goldstein, Jr. "Cementation of the Dakota sandstone, Northern Colorado"

The following paper was read by title.

J. Wyatt Durham, Arthur N. Dusenbury, L. Kehrer, R. M., Stainforth, and Benton Stone, "A Symposium: The age of the *Hannatoma* Mollusk fauna of South America"

The meeting adjourned at 4:00 P.M.

The annual business session of the Society was called to order at 11:30 A.M., Thursday, April 29, by President James A. Waters.

The minutes of the 1947 meeting were approved as published in the *Journal of Paleotology*, Vol, 21, No. 4 (July, 1947).

The following reports were given.

1. *Report of the Editor of the Journal of Paleontology* (*J. Marvin Weller*).—Volume 21 of the *Journal of Paleontology*, issued in conjunction with the Paleontological Society in 1947, contains 603 pages and 84 collotype plates. Published in it are 43 paleontological papers, 3 bibliographies, 1 paper each on stratigraphy, correlation, nomen-

clature; and technique, 29 notes, 7 reviews, and data relating to the activities and memberships of the two societies.

The March, July, and November issues were prepared by your editor on behalf of the Society of Economic Paleontologists and Mineralogists. These numbers consist of 333 pages and 36 collotype plates, an increase of 12 pages and a decrease of 9 plates as compared with the previous volume. The contributions in these numbers may be classifield as follows.

	Paleozoic	*Mesozoic*	*Cenozoic*
Foraminifera	4	2	5
Sponges	2		
Graptolites	1		
Conodonts	5		
Crinoids	1		
Starfish		1	
Brachiopods	1		
Pelecypods		2	1
Cephalopods	2	2	
Trilobites	1		
Ostracodes	1	2	5
Vertebrates		1	

Ten of these contributions describe or name fossils from foreign countries. In addition, three papers are devoted to nomenclature, two to bibliography and one to techniques. The number of manuscripts submitted to the editor for publication is steadily increasing and it may soon become necessary to refuse some good papers or to increase the size of the *Journal* numbers. With the approval of the Council of the Society, arrangements have been made with Edwards Brothers of Ann Arbor, Michigan, to republish in facsimile Volume 1 of the *Journal*.

2. *Report of the Editor of the Journal of Sedimentary Petrology* (*W. H. Twenhofel*).—Eighteen articles covering 126 pages were published in Volume 17 of the *Journal of Sedimentary Petrology*. In addition, there was an article prepared by K. O. Emery, with the assistance of R. Dana Russell, which was intended as a guide for those preparing papers intended for publication in the *Journal*. This article was entitled "Suggestions to Contributors." Only one review was published during the year 1947 and there were two announcements.

The members of the Society of Economic Paleontologists and Mineralogists do not use the *Journal* as much as the editor would desire. The future of the *Journal* requires that enough articles be submitted that an adequate supply can be had at all times. The editor has had to depend to a larger extent than he has wished on persons who were not members of the Society.

3. *Report of the Secretary-Treasurer* (*H. B. Stenzel*).—

BACK VOLUME SALES

Back volumes of the Journal of Paleontology	$2,010.80
Back volumes of the Journal of Sedimentary Petrology	693.43

PRINTING AND ENGRAVING BILLS FOR 1947

Journal of Paleontology

	Banta Printing Bills	*Meriden Engraving Bills*	*Total Printing and Engraving Bills*	*S.E.P.M. Total Printing and Engraving Bills*
Number 1 (January)*	$ 687.40	$ 493.01	$1,180.41	
Number 2 (March)	1,007.34	583.08	1,590.42	1,590.42
Number 3 (May)*	1,138.95	349.76	1,488.71	
Number 4 (July)	1,135.72	245.08	1,380.80	1,380.80
Number 5 (September)*	1,002.84	592.95	1,595.79	
Number 6 (November)	1,128.92	382.84	1,511.76	1,511.76
	$6,101.17	$2,646.72	$8,747.89	$4,482.98
(1946 Totals)	($5,054.58	($2,297.46)	($7,352.04)	($3,787.74)

* Odd numbers paid by Paleontological Society.

Journal of Sedimentary Petrology

Number 1 (April)	$ 304.03
Number 2 (August)	510.51
Number 3 (December)	460.63
	$1,275.17
(1946 Total)	($1,208.64)

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	March 1948	*March 1947*	*March 1946*
1. S.E.P.M. Membership:			
Active Members	321	306	279
Associate Members	101	90	77
TOTAL	422	396	356
2. Journal of Paleontology Mailing List:			
S.E.P.M. Active Members	239	230	218
S.E.P.M. Associate Members	67	58	49
Subscribers	464	371	380
P.S. Members	395	351	343
TOTAL	1,165	1,010	990
3. Journal of Sedimentary Petrology Mailing List:			
S.E.P.M. Active Members	166	156	139
S.E.P.M. Associate Members	38	31	26
Subscribers	378	266	283
TOTAL	582	453	448
4. Number of pages in 1947 Journal of Paleontology	603 (633, 1946)		
5. Number of plates in 1947 Journal of Paleontology	84 (90, 1946)		
6. Total edition of 1947 Journal of Paleontology	1,400 (1,300, 1946)		
7. Number of pages in 1947 Journal of Sedimentary Petrology	139 (132, 1946)		
8. Total edition of 1947 Journal of Sedimentary Petrology	700 (600, 1946)		
New Members from March 1, 1947, to March 1, 1948	24 (32, 1946–1947)		
New Associates from March 1, 1947, to March 1, 1948	17 (16, 1946–1947)		
Transfers to active membership, March 1, 1947, to March 1, 1948	3 (2, 1946–1947)		
Reinstatement to active membership, March 1, 1947, to March 1, 1948	1 (3, 1946–1947)		

FINANCIAL STATEMENT FOR THE YEAR ENDED DECEMBER 31, 1947

BALANCE SHEET AT DECEMBER 31, 1947

ASSETS

CURRENT ASSETS:		
Demand deposits		$ 8,089.84
Savings deposit		2,299.44
Accounts receivable less reserve, $23.88		79.25
Total current assets		$10,468.53
PUBLICATIONS:		
Journals of Paleontology:		
Issued prior to 1947—23,646 journals at $.50 each (3,961 complete volumes)	$11,823.00	
Issues 1 to 6 of 1947—1,245 journals at cost	1,341.11	
Journals of Sedimentary Petrology:		
Issued prior to 1947—3,850 journals at $.50 each (1,213 complete volumes)	1,790.00	
Issues 1, 2, and 3 of 1947—344 journals at cost	200.59	15,155.00
FURNITURE AND FIXTURES less reserve, $493.34		47.09
		$25,670.62

LIABILITIES AND SURPLUS

CURRENT LIABILITIES:		
Accounts payable		$ 1,442.58
Amount payable to Paleontological Society		1,186.36
TOTAL CURRENT LIABILITIES		$ 2,628.94
DEFERRED INCOME:		
Subscriptions to journals	$ 2,138.83	
Membership dues for 1948 and 1949	1,444.87	3,583.70
SURPLUS (per attached statement)		19,457.98
		$25,670.62

STATEMENT OF INCOME AND SURPLUS FOR YEAR ENDED DECEMBER 31, 1947

INCOME:		
Membership dues and subscriptions:		
Journal of Paleontology and Sedimentary Petrology	$ 904.00	
Journal of Paleontology	3,873.60	
Journal of Sedimentary Petrology	1,451.90	$ 6,229.50
Sales of back numbers:		
Journal of Paleontology	$1,893.80	
Journal of Sedimentary Petrology	775.50	2,669.30
Sales of plates and reprints		382.41
Advertising		68.69
Donation from The American Association of Petroleum Geologists		2,000.00
Miscellaneous		22.82
		$11,372.72
Less: Proportion of income accrued to Paleontological Society		1,186.36
		$10,186.36
COSTS AND EXPENSES:		
Cost of printing:		
Journal of Paleontology	$4,580.40	
Journal of Sedimentary Petrology	1,174.14	
	$5,754.54	
Clerical salaries	1,230.00	
Office supplies and expenses	309.84	
Office rent	598.00	
Expense of moving office	194.40	
Insurance and bond	54.55	
Postage, telegraph, and delivery expense	386.88	
Audit fee	100.00	
Taxes	29.24	
Depreciation	54.04	
Miscellaneous	50.95	
	$8,762.44	
Adjustment for decrease in inventory of publications	690.11	9,452.55
NET INCOME		$ 733.81
SURPLUS AT DECEMBER 31, 1946		18,724.17
SURPLUS AT DECEMBER 31, 1947		$19,457.98

CERTIFICATE OF INDEPENDENT PUBLIC ACCOUNTANTS

To the Council
of Society of Economic Paleontologists and Mineralogists:

We have examined the balance sheet of SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS at December 31, 1947 and the statement of income and surplus for the year then ended, have

reviewed the system of internal control and the accounting procedures of the Society and, without making a detailed audit of the transactions, have examined or tested accounting records of the Society and other supporting evidence, by methods and to the extent we deemed appropriate. Our examination was made in accordance with generally accepted auditing standards and included all procedures which we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the position of SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS at December 31, 1947, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

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TULSA, OKLAHOMA
January 28, 1948

4. *Report of the Committee on Awards for Outstanding Papers (W. C. Krumbein, Chairman).*—Because of problems connected with the establishment of criteria for excellence, the selection of reviewing committees, and the question of financing award for outstanding papers in paleontology and sedimentation, the Committee believes that no action should be taken at this time.

It was moved, seconded, and approved that all reports be accepted.

5. *Report of the Research Committee (W. H. Twenhofel, Chairman).*—The Research Committee of the S.E.P.M., following the annual meeting of the Society in Los Angeles in 1947, had a meeting to consider possible programs for the year 1947–48. It was decided to continue along the lines of previous years and to arrange a symposium for the annual meeting in 1948. Considerable correspondence lead to selection of the subject "Environmental Significance of Dwarfed Faunas." Five papers were planned and prepared as follows.

"Protozoa," by Cecil G. Lalicker, University of Kansas

"Brachiopoda," by Preston E. Cloud, Harvard University

"Ammonoidea," by Bernhard Kummel, Bureau of Economic Geology of Texas

"Mollusca (Exclusive of Ammonoidea)," by H. B. Stenzel, Bureau of Economic Geology of Texas

"Crustacea," by Harold W. Scott, University of Illinois

This symposium was held on the afternoon of April 28. Papers elicited considerable discussion in which M. K. Elias, Ben Cox, Raymond Moore, and others participated.

On motion of H. B. Stenzel, the report of the report of the Research Committee was accepted and the committee was discharged. An expression of thanks was extended to Dr. Twenhofel for the keen way in which he has kept the program running and for the great effort he has put into the committee for the past years.

6. *American Geological Institute.*—The following Articles of Organization of the proposed A.G.I. were read.

Article I—Name. The name of this organization shall be the AMERICAN GEOLOGICAL INSTITUTE, an instrument of the National Research Council which is an agency of the National Academy of Sciences.

Article II—Purpose. The purpose of this organization is the advancement of geology and its application to human welfare by providing a means for the cooperation of organizations active in the fields of pure and applied geology.

Article III—Membership.

1. The following organizations are eligible for initial membership in the Institute and shall be known as Member Organizations.

American Association of Petroleum Geologists
American Geophysical Union
American Institute of Mining and Metallurgical Engineers
Geology Society of America
Mineralogical Society
Paleontological Society
Seismological Society of America
Society of Economic Geologists
Society of Economic Paleontologists and Mineralogists
Society of Exploration Geophysicists
Society of Vertebrate Paleontology

2. Other non-profit organizations of national scope may be admitted as Member Organizations by the approval of two-thirds of the Member Organizations.

3. Any local, regional, or national nonprofit organization interested in geological sciences may, upon appropriate action by the Board of Directors, be designated as an

Affiliate with responsibilities and privileges determined by the Board of Directors.

4. Any organization interested in geological sciences, which contributes to the support of the Institute may, by action of the Board of Directors, be admitted as an Associate of the American Geological Institute.

Article IV—Board of Directors.

1. The control and management of the affairs of the Institute shall be vested in Board of Directors consisting of two Directors designated by each Member Organization and such other Directors as are hereinafter provided.

2. The Directors shall be designated for a term of two years, except that initially one Director from each Member Organization shall be designated for one year. In case of a vacancy the Member Organization concerned shall make a new designation to complete the unexpired term. For purposes of determining the terms of Directors, a year shall be construed as the period extending from the close of one annual meeting to the close of the next.

3. The Chairman of the National Research Council and the Chairman of the Division of Geology and Geography of the National Research Council, or their designates, shall be Directors *ex-officio*, and the National Research Council shall have the right to appoint one additional Director.

Article V—Officers. The Officers of the Institute shall be a President, a Vice-President and a Secretary-Treasurer, who shall be elected annually by the Board of Directors from among its members. They shall take office at the close of the meeting at which they are elected. The President, or in his absence, the Vice-President, shall preside at meetings of the Board of Directors. The duties of the officers shall be those usually devolving upon such officers, except as may be determined by the Board of Directors.

Article VI—Meetings. The Annual Meeting of the Board of Directors for the election of officers and for the transaction of such other business as may properly come before the meeting shall be held at such time and place as the President may designate. Other meetings may be called at the discretion of the President. Directors representing two-thirds of the Member Organizations shall constitute a quorum at any meeting, and a majority vote of the Directors present shall be required for the transaction of business. A Member Organization may designate alternates for any of its Directors unable to attend.

Article VII—Executive Committee. There shall be an Executive Committee of the Board of Directors, which shall consist of the officers and such other members as the Board of Directors may designate.

The Executive Committee shall be charged with the conduct of such business as may be delegated to it by the Board of Directors and shall have authority to act for the Board in the interim between meetings of the Board to such extent as the Board may authorize.

With the prior approval of the Board of Directors, the Executive Committee may establish a headquarters office and employ qualified personnel for conducting the business of the Institute.

Article VIII—Other Committees. The Board of Directors shall have the power to establish other committees, appoint their members and assign their duties. The members of such commitees may or may not be members of the Board. The term of each such committee, unless otherwise specified, shall expire at the close of the next annual meeting of the Board following the appointment of the committee.

Article IX—Finances. The Institute shall have the power to solicit and receive funds. The Board of Directors shall have control of the management and disbursement of the funds of the Institute. No Member Organization shall be subject to assessment in any amount for any purpose.

Article X—Amendments. Amendments to these Articles of Organization may be proposed in writing to the Board of Directors by any Director. Upon at least thirty days' notice, they shall be considered by the Board of Directors, and, if approved, shall become effective upon ratification by the National Academy of Sciences and by two-thirds of the Member Organizations.

Article XI—Rules and Regulations. The Board of Directors may adopt such Rules and Regulations as it may deem necessary or desirable for the conduct of the affairs of the Institute.

Article XII—Resignation. Any Member Organization may resign by giving proper written notice to the President of its withdrawal from the Institute, and thereupon its membership and the terms of office of the Directors designated by it shall terminate.

Affiliates and Associates may withdraw from membership following proper notification in writing to the Board of Directors.

Article XIII—Termination of Membership.

1. A Member Organization may be dropped from membership upon vote of two-thirds majority of the Board of Directors, present and voting at any meeting. Such action may not be taken earlier than six months after notice of the proposed action has been given to the Member Organization.

2. An Affiliate or Associate may be dropped by a vote of a majority of the Directors present and voting at any meeting.

Article XIV—Ratification. These Articles of Organization shall become effective upon their approval by the National Academy of Sciences and upon their ratification by seven of the organizations listed in Article III.

Raymond C. Moore moved that the Society ratify the new Articles of Organization of the American Geological Institute and instruct the Council of the Society to notify the Institute of this action. Motion was seconded and approved, and R. Dana Russell, incoming president, was instructed to appoint two Directors as indicated in Article IV.

A review of the Bikini Oil Program was presented by R. Dana Russell, and on motion of Raymond C. Moore the Society approved the scientific objectives of the program and instructed the Council to write a letter of endorsement.

On motion of W. C. Krumbein, the annual report of the Joint Committee on Zoological Nomenclature for Paleontology in America was accepted.

It was announced by James A. Waters that Raymond C. Moore and R. Dana Russell had been appointed official delegates of the S.E.P.M. to the International Geological Congress, London, England. President Waters also announced that Volume I of the Journal of Paleontology is in the process of being reprinted and will be available at $6.50 per clothbound copy or $6.00 paperbound copy.

The results of the election of officers by mailed ballot, for the new year, were announced by outgoing President Waters as follows: President: R. Dana Russell; Vice-President: J. B. Garrett, Jr.; Secretary-Treasurer: H. B. Stenzel.

The business session adjourned at 12:00 P.M., Thursday, April 29.

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OFFICERS OF THE SOCIETIES

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

For the year ending March 1949

President, R. Dana Russell, San Diego, Calif.

First Past-President, James A. Waters, Dallas, Tex.

Second Past-President, F. W. Rolshausen, Houston, Tex.

Vice-President, J. B. Garrett, Jr., Houston, Tex.

Secretary-Treasurer, H. B. Stenzel, Austin, Tex.

Editors

J. Marvin Weller, Chicago, Ill., for paleontology.

W. H. Twenhofel, Orlando, Fla., for mineralogy.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

For the year ending March 1949

President, Paul Weaver, Houston, Tex.

Past-President, C. E. Dobbin, Denver, Colo.

Vice-President, Roy M. Barnes, Los Angeles, Calif.

Secretary-Treasurer, J. V. Howell, Tulsa, Okla.

Editor, C. L. Moody, Shreveport, La.

THE PALEONTOLOGICAL SOCIETY

For the year ending December 1948

President, Wendell Woodring, Washington, D.C.

Vice-President, C. Wythe Cooke, Washington, D.C.

Secretary, H. E. Vokes, Baltimore, Md.

Treasurer, Frank M. Swartz, State College, Pa.

Editor, A. Scott Warthin, Poughkeepsie, N.Y.

Chairman, Pacific Coast Section, J. Wyatt Durham, Berkeley, Calif.

Ex-Presidents

Chester Stock, Pasadena, Calif., 1945.
J. Brookes Knight, Washington, D. C., 1946.
R. C. Moore, Lawrence, Kans., 1947.

JOINT COMMITTEE ON ZOOLOGICAL NOMENCLATURE FOR PALEONTOLOGY IN AMERICA

Sponsored by the Society of Economic Paleontologists and Mineralogists, The Paleontological Society, and the Society of Vertebrate Paleontology in support of the International Commission on Zoological Nomenclature.

Policy Board

Raymond C. Moore, *Chairman* (SEPM), J. B. Reeside, Jr., (PS); A. S. Romer (SVP)

Members

John B. Reeside, Jr. G. Arthur Cooper Norman D. Newell George Gaylord Simpson	1946–1948
Alfred S. Romer Donald L. Frizzell A. Myra Keen Katherine V. W. Palmer	1947–1949
J. Brookes Knight Raymond C. Moore G. Winston Sinclair John W. Wells	1948–1950

Address all communications to the chairman, Raymond C. Moore, University of Kansas, Lawrence, Kansas.

THE GEOLOGICAL SOCIETY OF AMERICA

For the year ending December 1948

President, James Gilluly, Los Angeles, Calif.
Past-President, A. I. Levorsen, Stanford University, Calif.

Vice-Presidents

Chester K. Longwell, New Haven, Conn.
Kirk Bryan, Cambridge, Mass.
Raymond C. Moore, Lawrence, Kans.
Martin J. Buerger, Cambridge, Mass.

Secretary, H. R. Aldrich, New York, N. Y.

Treasurer, W. O. Hotchkiss, Scarsdale, N. Y.

Councillors

T. S. Lovering C. W. Knight Maurice Ewing	1946–1948
C. A. Anderson, Prescott, Ariz. Ernest Cloos, Baltimore, Md. M. King Hubbert, Houston, Tex.	1947–1949
G. M. Fowler, Joplin, Mo. F. J. Pettijohn, Chicago, Ill. Earl Ingerson, Washington, D.C.	1948–1950

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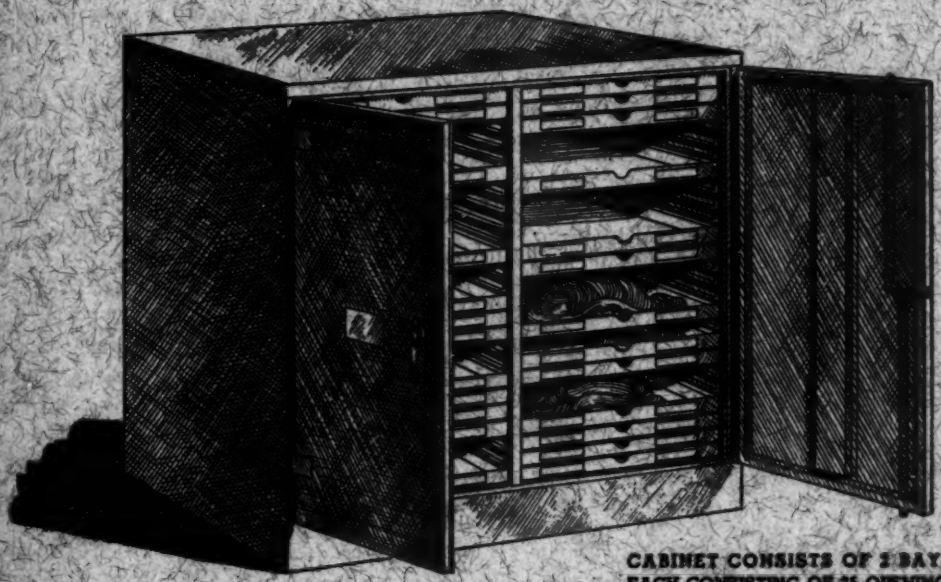

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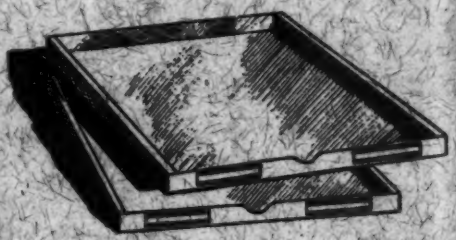

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NEWARK 2, NEW JERSEY, U.S.A.